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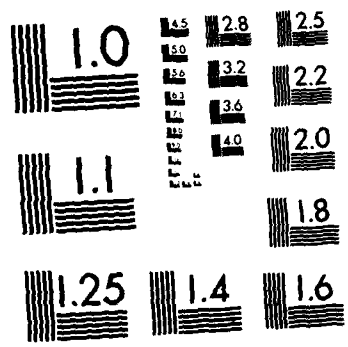

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A DECISION MODEL FOR EVALUATING LAND DISPOSAL OF HAZARDOUS WASTES

Captain Ken M. Stoner, USAF

LSSR 65-82

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER LSSR 65-82	2. GOVT ACCESSION NO. AD-A123 742	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A DECISION MODEL FOR EVALUATING LAND DISPOSAL OF HAZARDOUS WASTES		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Ken M. Stoner, Captain, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Systems and Logistics Air Force Institute of Technology, WPAFB OH		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Communication and Humanities AFIT/LSH, WPAFB OH 45433		12. REPORT DATE October 1982 13. NUMBER OF PAGES 131
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Approved for public release: IAW AFR 190-17.

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LYNN E. [illegible]

Dean for [illegible] Professional Development

Air Force Institute of Technology (AIC)

Wright-Patterson AFB OH 45433

16 DEC 1982

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Industrial Wastes
Solid Wastes
Waste Disposal
Waste Management
Waste

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thesis Chairman: Alfred B. Hicks, Captain, USAF

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This study examined three land disposal options for military wastes which are deemed hazardous through regulations that support the Resource Conservation and Recovery Act of 1976. The study offers a procedure which helps base-level Air Force managers determine whether industrial wastewater treatment sludges should be disposed in a landfill using an arrangement that is either all-government, all-contracted, or partially-contracted.

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LSSR 65-82

A DECISION MODEL FOR EVALUATING LAND DISPOSAL OF HAZARDOUS WASTES

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Technical Management

By

Ken M. Stoner, BS
Captain, USAF

October 1982

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This thesis, written by

Captain Ken M. Stoner

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN TECHNICAL MANAGEMENT

DATE: 17 October 1982

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ACKNOWLEDGMENTS

This study is dedicated to indirectly conserving the country's resources in behalf of my children, Scott and Tana.

Special gratitude is acknowledge for the following:

Captain Alfred Hicks, because he displayed patience and tolerance while my concepts were developing;

Dr. Richard Fenno, because he generously offered much helpful assistance;

Mr. Steve Coyle, because he contributed support and enthusiasm when everything seemed futile;

Mrs. Suzanne Weber, because her secretarial expertise greatly reduced problems associated with producing this final document; and

Lieutenant Colonel David Lee, because he continued to offer support even after his retirement.

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LIST OF ABBREVIATIONS

AF	United States Department of the Air Force
AFESC	Air Force Engineering and Services Center
AFLC	Air Force Logistics Command
AFMEA	Air Force Management Engineering Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	cubic meter
cy	cubic yard
DOD	Department of Defense
DOT	Department of Transportation
EPA	Environmental Protection Agency
IWTP	Industrial wastewater treatment process
mt	metric ton
NSWMA	National Solid Wastes Management Association
OSHA	Occupational, Safety and Health Act
PWS	Performance Work Statement
RCRA	Resource Conservation and Recovery Act
sq yd	square yard
TSD	Treatment, storage, and disposal facility
UTTR	Utah Test and Training Range
yr	year

CHAPTER I

INTRODUCTION

This study examines land disposal options for military wastes which are deemed hazardous according to regulations that implement the Resource Conservation and Recovery Act of 1976 (RCRA). The study offers a three-step procedure for selecting the most ideal option based upon currently identifiable influences. The selection procedure is referred to as a decision model throughout the study. The decision model is a qualified answer to the following problem.

Problem Statement

How can Department of Defense (DOD) managers evaluate options for the disposal of hazardous waste? The problem is restricted by limiting consideration to the following main objective.

Research Objective

The main objective is to develop a procedure for determining whether the Air Force's industrial wastewater treatment process (IWTP) sludges should be disposed in secure landfills on DOD property or in secure landfills on private property.

Limitations of the Research Objective

Figures 1, 2a, and 2b illustrate the manner in which the problem's scope has been limited.

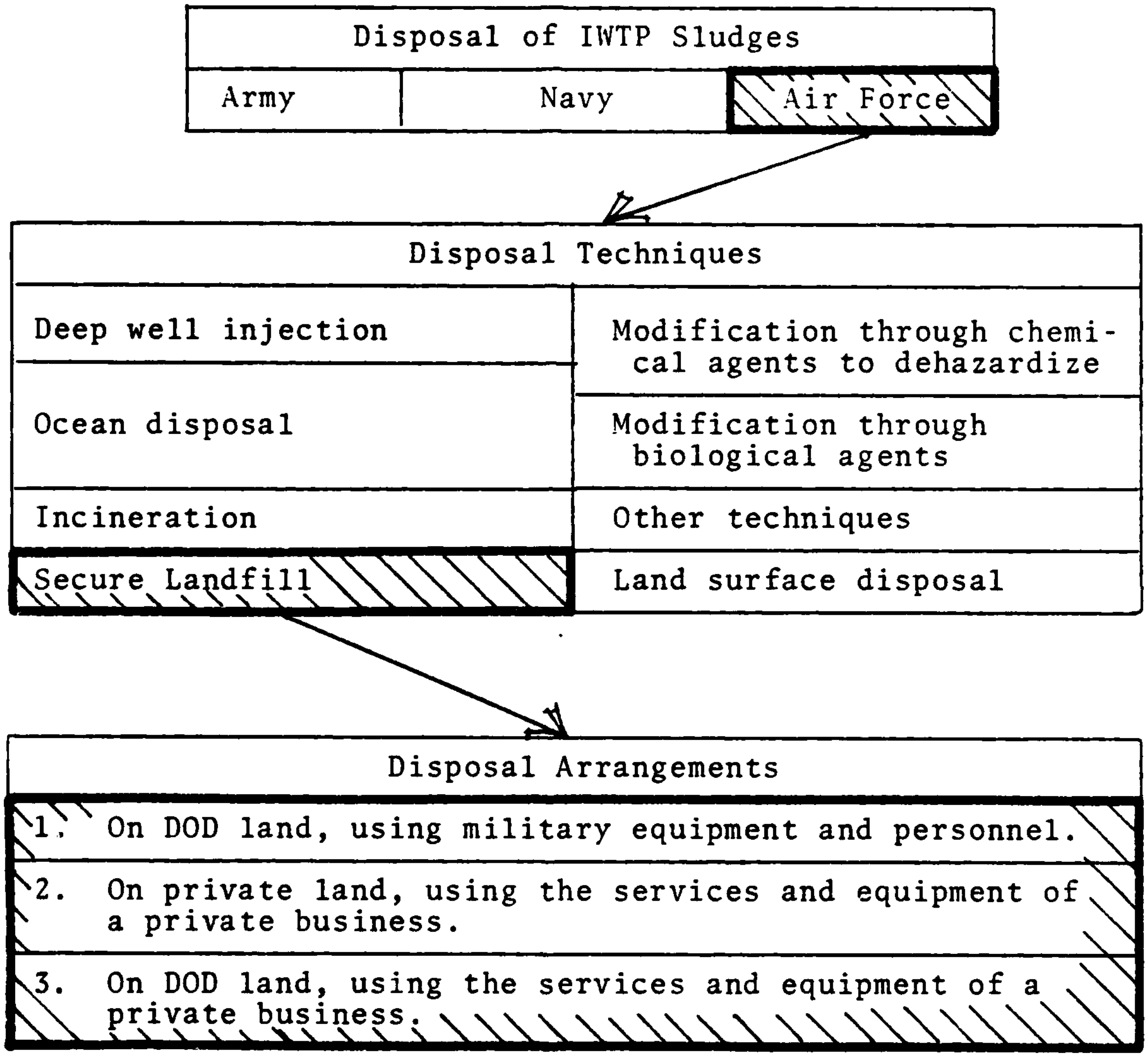


Fig 1. Scoping the Problem - Disposal Options (Not to Scale)

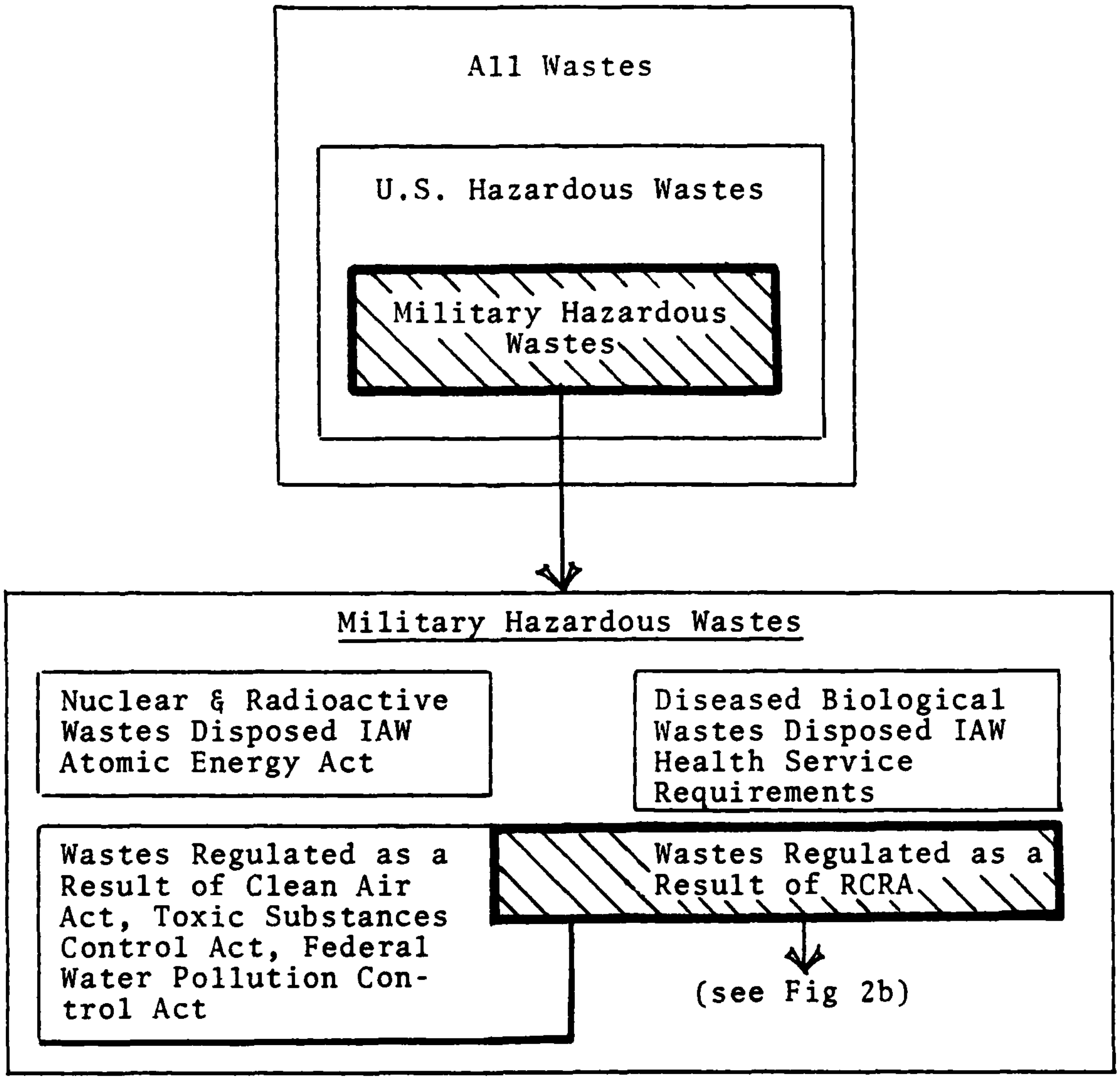
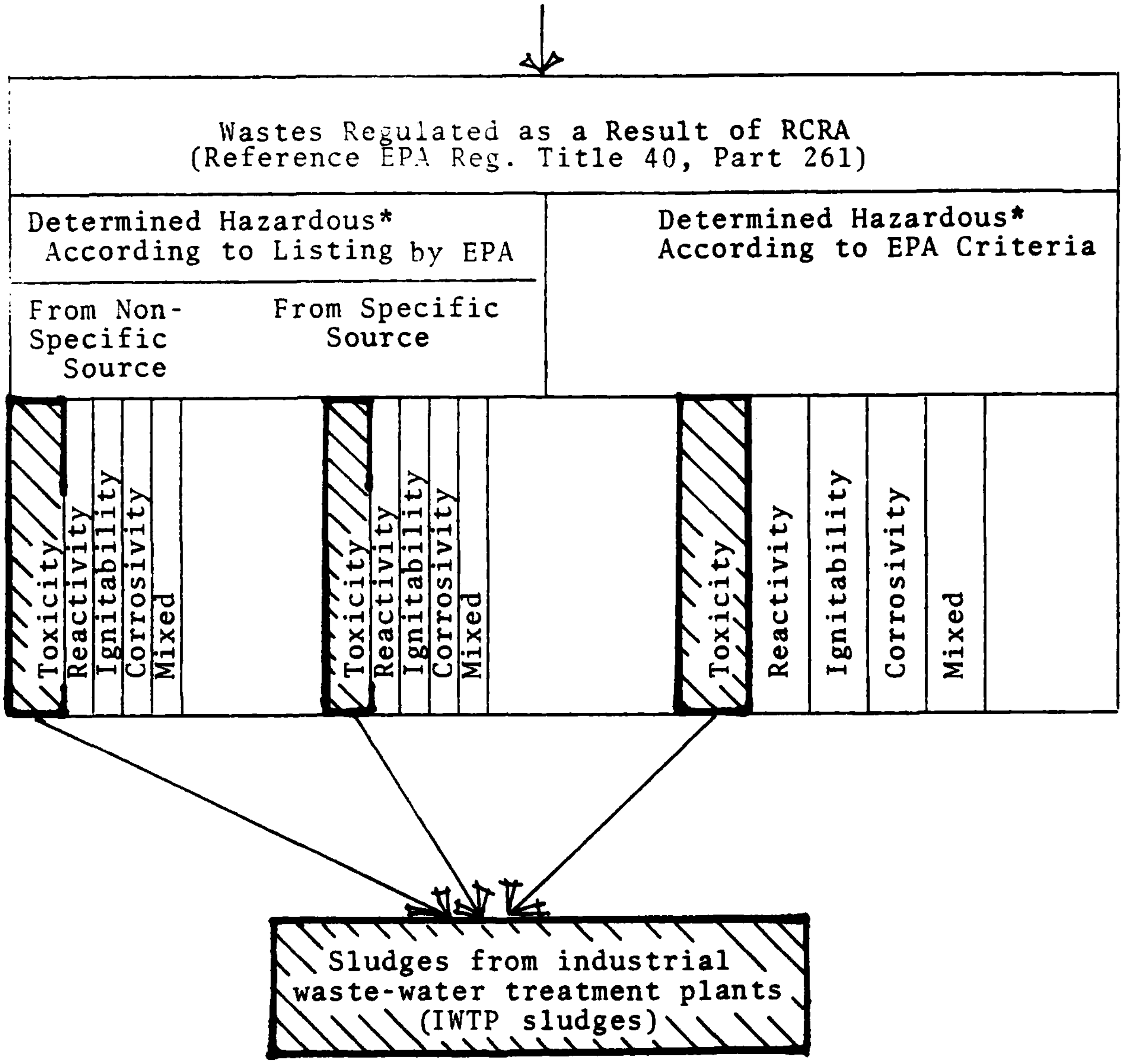


Fig 2a. Scoping the Problem - Type of Waste
(Not to Scale)



*Codes designating reason for hazardous label. Mixed = various combinations of toxicity, ignitability, reactivity, and corrosivity.

Fig 2b. Scoping the Problem - Type of Waste (Not to Scale)

The main objective focuses on a segment of the problem as defined below:

1. The research objective is limited to evaluations which Air Force managers must face. According to a prevalent notion within the Air Force, the actual determination of how to manage hazardous waste should occur at base level (11). The model is directed at aiding Air Force managers at the base level, but the model's use by others within the DOD is still valid when similar circumstances exist.

2. The research objective limits the evaluation to one disposal technique, the secure landfill (see Figure 1). The costs and intangible concerns associated with all other disposal and treatment techniques--which include techniques such as incineration, deep-well injection, ocean disposal, and alteration by chemical or biological agents, etc.--are not part of the decision model since land disposal has been the dominant disposal practice both inside and outside the DOD. Pre-RCRA estimates suggest that 70 percent or more of the total civilian solid wastes were disposed of by a land-based method (8; 9; 25:283). One pre-RCRA study indicated that the Air Force disposed of more than 95 percent of its waste in landfills (2:115). This dominant, historical function for landfills will undoubtedly influence current base-level consideration of using secure landfills.

3. The research objective is limited to a specific category of hazardous wastes (see Figures 2a and 2b). Some sludges have characteristics that meet criteria established

by the Environmental Protection Agency (EPA) and thus are categorized as hazardous (55:Part III). This study considers only the category of wastewater treatment sludge deemed hazardous because of its toxicity. At least 19 hazardous waste classifications which are listed by the EPA are included in this category (55:33123-33124) (see Tables 1 and 2 in Chapter II).

4. The research objective compares disposal on military-controlled federal land versus disposal on properly permitted, private property. No comparison is made with secure landfills either on state-owned land or on municipally-owned land. The comparison is further limited to three disposal arrangements. In the first arrangement, the DOD uses military personnel or federal civilian employees, and DOD equipment and DOD materials to dispose of the sludges on DOD land. This arrangement is called the all-military option. A second arrangement is called the complete-contract option, in which the DOD relies upon a civilian contractor for waste pickup, transport, and final disposal on private property. In the third arrangement, called partial-contract, the DOD disposes of waste in a secure landfill on DOD land. However, the waste is picked up and transported by a civilian contractor who constructs, operates, maintains, and monitors the disposal site.

This study uses the following three sub-objectives as a means of satisfying the main research objective.

Sub-Objectives

1. Identify major influential issues.
2. Develop a decision model.
3. Suggest how policy affects use of the model.

The response for the first sub-objective is partially based upon issues noted during the survey of literature since 1972. The response is also based upon inputs from individuals in key roles who were contacted during July 1981 through August 1982. Information sources applied only to disposal within the United States, excluding disposal in foreign landfills.

Sub-objective 1, dealing with major influential issues, is developed in Chapter II. The development of the proposed decision model and its limitations are described in Chapter III. The fourth chapter applies the proposed decision model in actual circumstances at Hill AFB to demonstrate the model's usefulness. The final chapter includes an explanation of some relationships between policy and the model, along with recommendations on how to remove some problems for future decision-making.

Justification for Research

Federal law, Air Force policy, and the Aerospace Corporation (an independent research organization) indicate that research into hazardous waste disposal has merit by providing impetus for investigating, planning, prioritizing, and examining. For example, RCRA encourages and makes federal financial

assistance available for investigations relating to the operation and economics of hazardous waste management (47: Sec 8001 (a), Sec 4008(a)(2)(A)). When resources are limited, the Air Force requires that environmental protection be planned and executed so that first priority is given to ensuring human health and safety, and second priority is given to promoting cost effectiveness (51:2(a)(4), 2(b)(13)).

The Aerospace Corporation recognized that both the costs and the availability of landfills are a concern for the military. It further noted that the use of private disposal facilities providing services on an area-wide basis as an alternative to individual military facilities may result in cost and environmental advantages and reduced public opposition. The Aerospace Corporation recommended the DOD "examine potential alternatives to this problem," and construct hazardous waste facilities on-site whenever use of commercial facilities is inappropriate (1:59). This impetus suggests the need for some procedure to evaluate alternative disposal arrangements.

A procedure for examining land disposal alternatives is needed in a specific case at Hill AFB, Utah (26). The Air Force Logistics Command (AFLC) is looking for a way to evaluate the feasibility and cost effectiveness for waste disposal options to use at Hill AFB. AFLC "needs to objectively scrutinize its disposal facilities to determine the desirability of continued operation [41]." The proposed decision model provides a standard way in which managers at Air Force bases can determine the desirability of three different disposal arrangements involving secure landfills.

CHAPTER II

BACKGROUND

Current issues influence decisions involving the selection of a particular disposal option. These issues are addressed under the following headings: Legislation/Regulation/Policy, Physical Capabilities, Risk Determination, and Costs. The first three headings support the first research sub-objective, which is to identify major influential issues.

Legislation/Regulation/Policy

The Resource Conservation and Recovery Act (RCRA) was enacted because other federal environmental laws did not adequately control the problems associated with land disposal methods which were being used across the nation (5). Before enactment of RCRA, Congress had determined that other environmental laws enacted during the early 1970's caused greater amounts of solid wastes, primarily in the form of sludges. These additional wastes added to the massive amount of wastes being deposited onto or into the nation's lands. Congress also discovered that the various methods of land disposal then in use were wasting discarded materials which could be reused; were contaminating the air, land, and both surface and subsurface water; and were presenting a danger to human health. RCRA is a major environmental law which was enacted by the United States Congress during the fall of 1976 to stop these

abuses and close the gap in controlling disposal activities (5). Subtitle C of this law is directed at managing the yearly estimated generation of fifty million metric tons of hazardous waste, an amount which is expected to increase in volume at an annual rate of eight percent (5; 47).

One of the law's goals is to protect both the natural environment and human health. In order to achieve this goal, RCRA promotes the development of techniques for handling, storing, transporting, disposing, and managing wastes. The protective goal of the law is directed at hundreds of wastes which are categorized as either non-hazardous waste or hazardous waste. According to RCRA, a waste is hazardous if its quantity, concentration, physical characteristics, or chemical characteristics cause an increase in mortality, serious irreversible illness, or incapacitating reversible illness when improperly managed. Wastes which pose a potential hazard to human health or the environment are also considered hazardous. RCRA applies to any entity receiving, generating, or handling solid waste, and it requires federal organizations, such as the military, to follow regulations which the Environmental Protection Agency (EPA) promulgates.

EPA regulations provide the specific criteria which implement the law. Under these regulations, sludges coming from the Air Force's industrial wastewater treatment plants are classified as hazardous because of toxic contaminants within the sludge (55:33084-33127). Table 1 lists EPA waste codes and the contaminants included within this group of

wastes. Other sludges may also be classified as hazardous due to toxicity if contaminants exceed a specified concentration (see Table 2).

TABLE 1

Listed Hazardous Sludges

EPA Waste Code	Toxic Contaminant
Having Significance to Military:	
F006	Cadmium, chromium, nickel cyanide (from electroplating operations)
K046	Lead (from manufacturing, formulation and loading of lead-based initiating compounds for explosives)
Other Sludges Having Similar Character:	
F012 K001 to K008 K032 K035 K037 K040 K041 K046 K057 K066	Note: All involve sludges deemed hazardous because of a toxic contaminant. All are formed from a wastewater treatment process. Cadmium, chromium, lead, cyanide, and other constituents are involved.
Source: (55:33131-33133)	

TABLE 2

Hazardous Contaminants

Contaminants		Maximum Milligrams Per Liter
D004	Arsenic	5.0
D005	Barium	100.0
D006	Cadmium	1.0
D008	Lead	5.0
D009	Mercury	0.2
D010	Selenium	1.0
D011	Silver	5.0
D070	Chromium	5.0
Source: (55:33119-33122)		

Within the military, responsibility for disposing of hazardous waste is divided among several agencies. The Defense Logistics Agency (DLA) is designated the central manager for disposal of the military's hazardous wastes in accordance with Defense Environmental Quality Program Policy Memorandum (DEQPPM) 80-5. However, DEQPPM 80-5 places "sludges and residues generated as a result of industrial plant processes or operations" in an excepted category (38). This exception results in each military service still being responsible for managing the disposal of its industrial wastewater treatment sludges in a manner which satisfies RCRA, EPA regulations and DOD requirements.

The Air Force Engineering and Services Center (AFESC) is the agency within the Air Force that disseminates technical instructions to fulfill the Air Force's management responsibility (24). The Directorate of Environmental Planning for AFESC began disseminating instructions to the Major Air Commands during the latter part of 1980. The third instruction reemphasized a policy established through DEQPPM 80-8, RCRA Hazardous Waste Management Regulations, which identified the Base Commander as the person formally responsible for meeting the requirements originating from RCRA. The instruction also stated that the Base Commander can delegate his responsibility to one of his organizations, such as Civil Engineering (48).

The Base Civil Engineer (BCE) is normally delegated the responsibility. The BCE's are de factor managers of the disposal activity involving industrial wastewater treatment

sludges. The managerial role means the BCE selects the plan of action using a combination of material, manpower, and money that coordinates with the expressed requirements in the law, DOD policy, and Air Force regulation.

The expressed EPA requirements that determine what issues the BCE must consider because of their influence upon cost are outlined in Appendix A. The outlined requirements do not specify a preferred technique for disposal of IWTP sludges, and the criteria and regulations identified in Appendix A allow an acceptable configuration for a secure landfill to vary due to peculiarities for different areas. These peculiarities include, but are not limited to, such things as:

- the extent of the ground monitoring system required
- the type and amount of equipment required at the site
- the type of security system needed
- the extent of documentation and reporting required
- the manner in which the wastes must be confined

For purposes of this study, a secure landfill is standardized to the configuration shown in Figures 3a, 3b, and 3c. The author's illustrated configuration will serve as the design reference in the absence of a definitive Air Force standard and will satisfy all known federal requirements.

Influences on the manager's decision due to requirements in other documents are less obvious. The documents listed below are described in greater detail because they can affect an Air Force manager's opinion of each disposal arrangement's attractiveness:

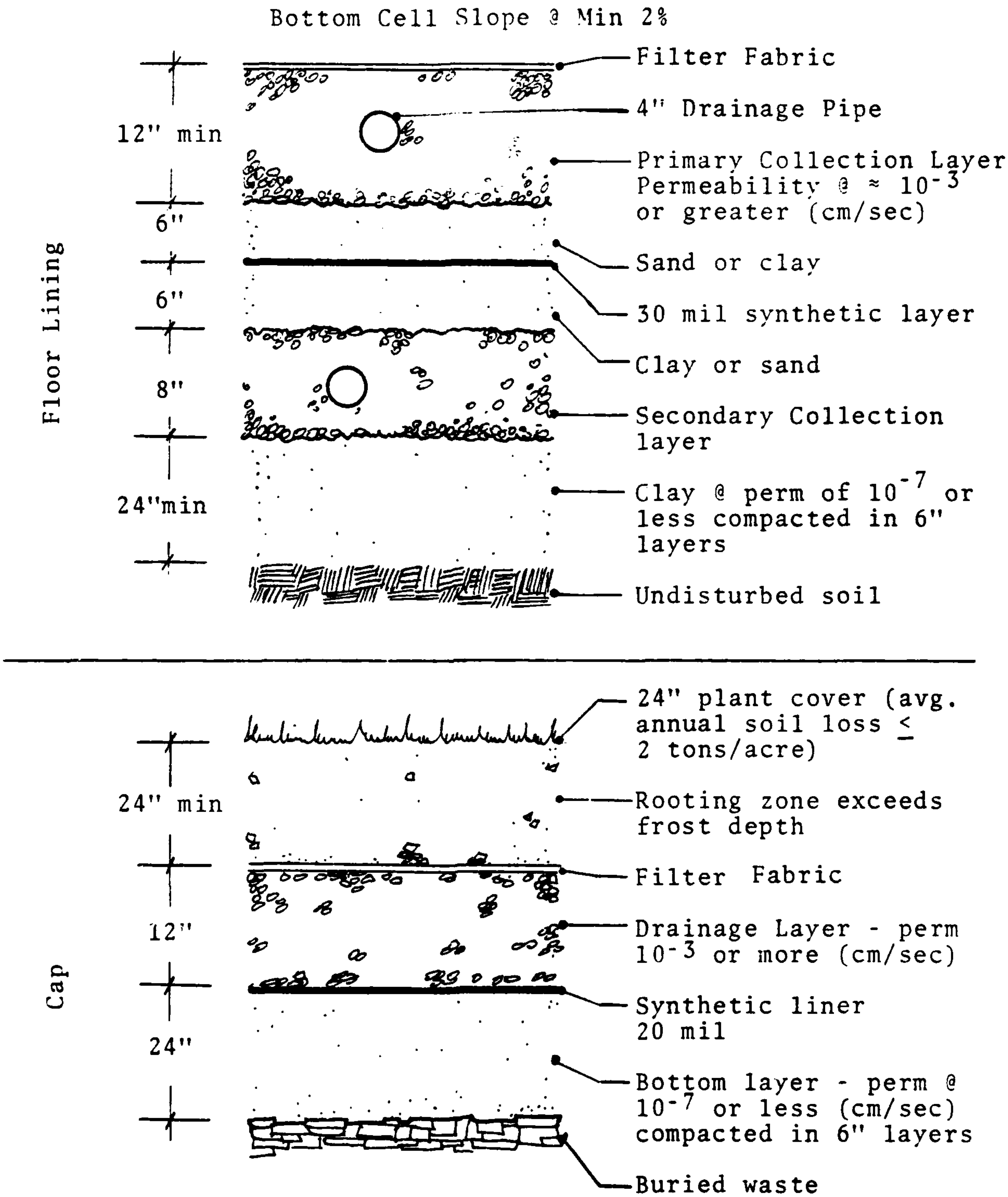


Fig 3a. Secure Landfill - Details for Reference
(54:8-33)

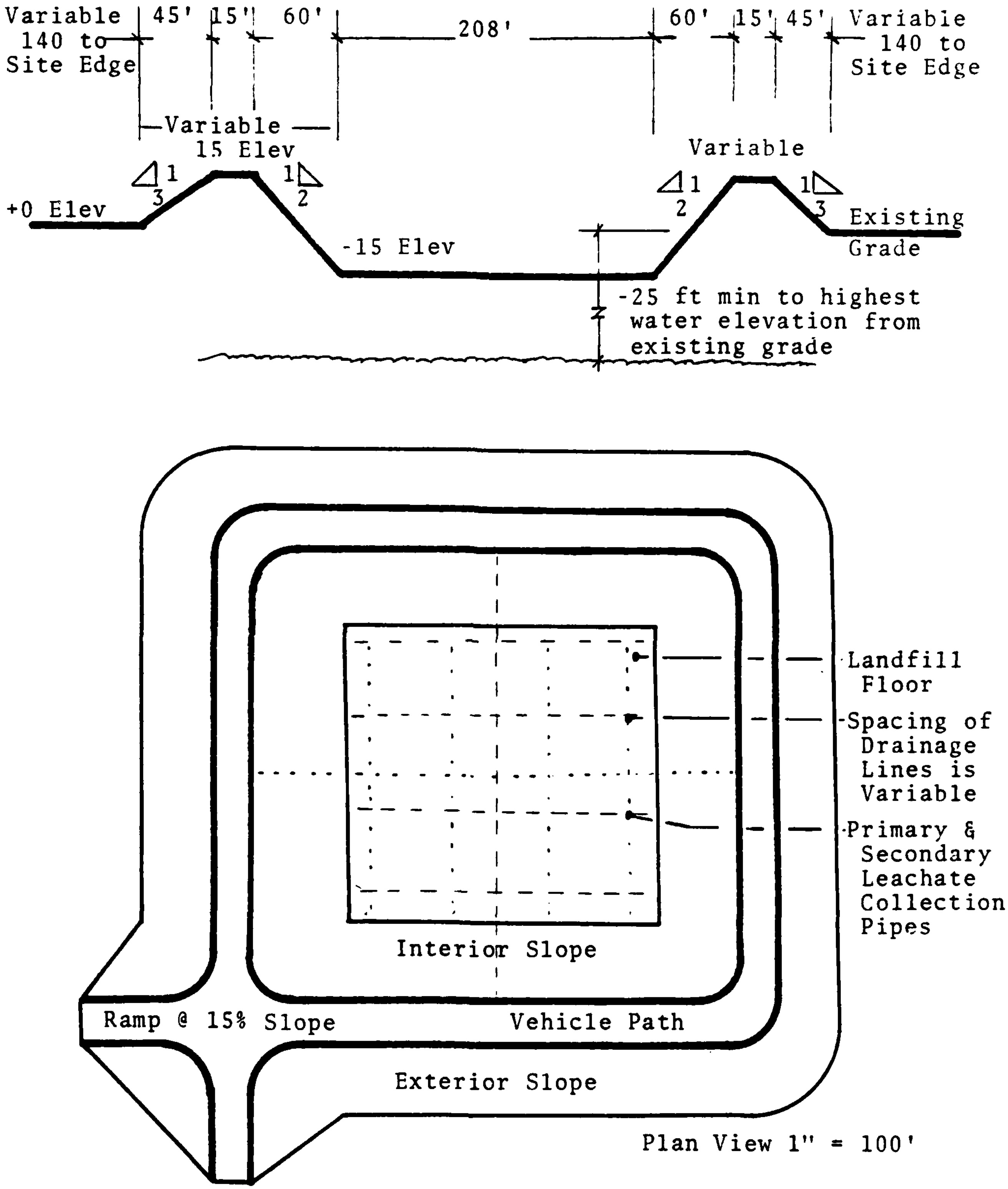
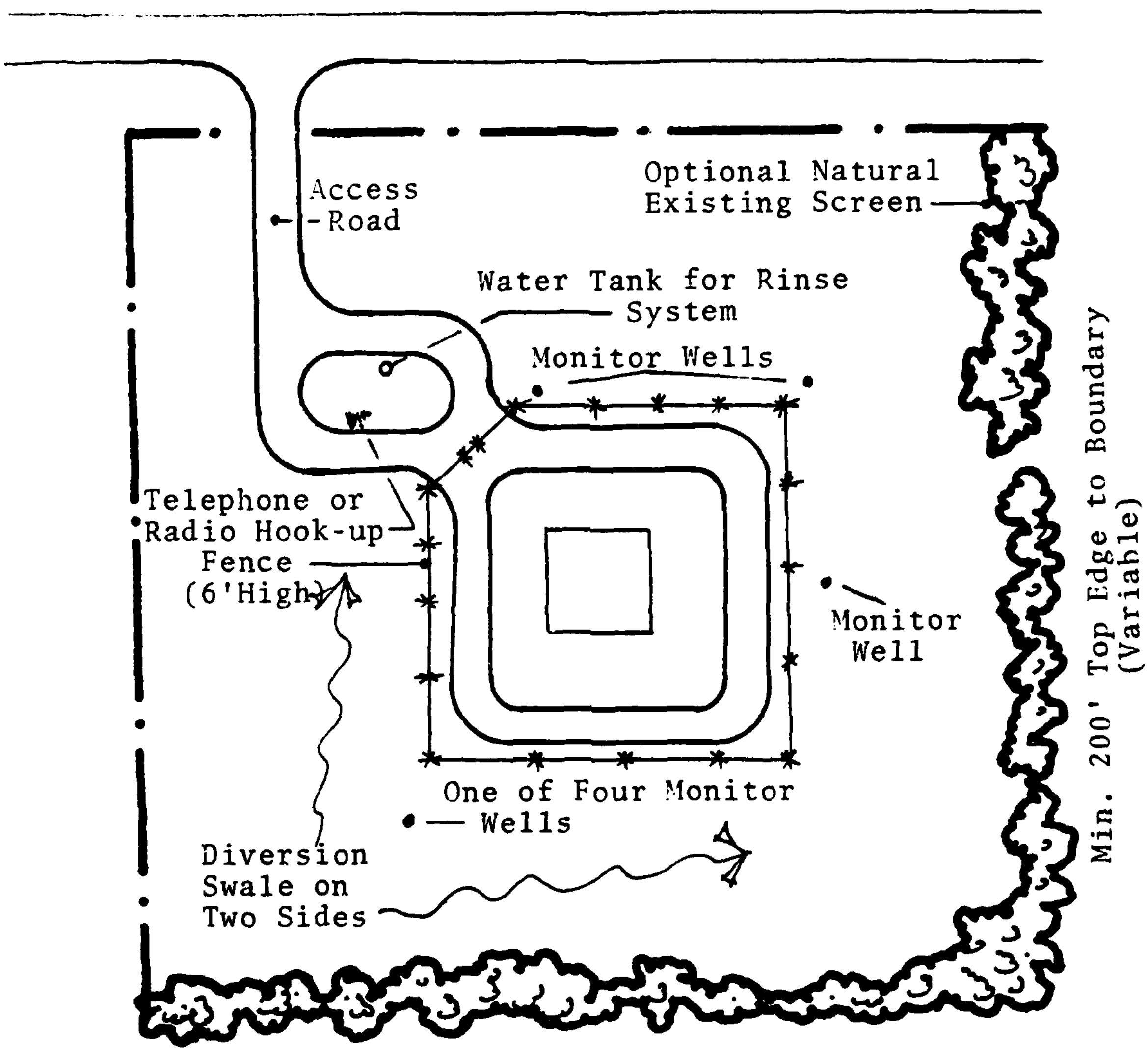


Fig 3b. Secure Landfill - Details for Reference (10)



(Typical Features--no scale)

Fig 3c. Secure Landfill - Site Plan for Reference
(43:212; 53; 55)

OMB A-76, "Policies for Acquiring Commercial or Industrial Products and Services Needed by the Government"

DOD 6050.8, "Storage and Disposal of Non-DOD-Owned Hazardous or Toxic Materials on DOD Installations"

[illegible]-1, Disposal of Real Property

AFR 78-2, Management of Industrial Facilities

AFR 19-1, Pollution Abatement and Environmental Quality

Contracts with civilians to dispose of military wastes are frequently managed by a legal agreement called a service contract. OMB A-76 presents the executive policies which establish whether a service should be done under contract with private sources or "in-house." The determination is made using the guidelines listed below (20):

- Consideration is first given to relying on private sources for needed services whenever private, capable sources are available.

- Economic comparisons should be used to decide how the work should be done when private performance is feasible and no inherently governmental function is involved.

- Only functions inherently governmental must be performed by government personnel.

The consensus among key personnel contacted during this study is that hazardous waste disposal is not a governmental function (28; 29; 30; 31). As a final note regarding contracts, master specifications applicable to service contracts for the recurring collection and disposal of hazardous wastes at Air Force installations have not yet been developed (3; 33; 36).

DOD Directive 6050.8 established DOD policy for the storage or disposal of non-DOD-owned toxic or hazardous materials on DOD installations. Under this policy, DOD

installations are not generally permissable disposal sites for non-DOD-owned hazardous material (52).

AF Regulation 87-4 implements DOD policy for declaring real property to be nonessential and thus to be available for other uses. Real property which is contaminated by toxic substances requires decontamination in accordance with the General Services Administration's (GSA) Regulation 41 CFR 101 prior to selling. AFR 87-4 implements both the GSA regulation and DOD Instructions by requiring the Air Force to fund the decontamination of its excess real property. The purpose is to prevent contaminated properties from becoming a hazard to the general public. Appendix B is an example of the certificate which must accompany the transfer of real property to clearly state the condition of the excess property. The decision to decontaminate or retain is based upon "break even" points as quoted:

> Fee Owned Land: Property will normally be retained under AF management if decontamination costs would exceed fair market value of the property after restoration to unrestricted use; or it would be less costly than decontamination to secure the property (security fencing and posting) and monitor the environment for 30 years to assure no migration of hazardous contamination from the site [56].

AFR 78-2 provides Air Force policy for the management of industrial facilities. Although the Air Force is phasing out some existing arrangements whereby contractors use government-owned facilities, AFR 78-2 exempts facilities for the operation and maintenance of government installations, or other services which support government-owned or controlled installations (50).

AFR 19-1 prioritizes efforts to carry out pollution control in the following order: 1) situations that constitute a hazard to the health or safety of man; 2) situations that are cost effective; and 3) situations that affect the recreational and esthetic value of natural resources. The regulation requires all practical efforts be made to dispose of pollutants in a manner that will not do the following:

- Expose people to concentrations of any agent (chemical, physical, or biological) hazardous to health

- Alter the natural environment so that an adverse effect is created with respect to human health or the quality of life

- Result in substantial harm to domestic animals, fish, shellfish, or wildlife

- Cause economic loss through damage to trees, agricultural crops, and other plants

- Impair recreational opportunity and natural beauty or cause groundwater contamination

Disposal by reprocessing, recycling, or reuse, when possible is also a stated policy, and an implied preference is to use municipal or regional waste disposal systems. However, when such systems are not "appropriate," Air Force managers must do whatever is necessary to satisfactorily dispose of wastes. This includes actions such as installing and operating waste treatment and disposal facilities. AFR 19-1 states that the manpower needed to satisfy these policies will come from existing resources within the function that has the requirement (51).

Physical Capabilities

In 1981 the Air Force disposed of hazardous waste totalling an estimated 14,779 tons. AFLC generated 77 percent of the total, and it is estimated that most of AFLC's wastes were IWTP sludges (13; 15). To estimate the total landfill area required for disposal of sludges, an annual generated quantity of 15,000 tons is assumed. This allows for some underestimates in reporting and for some possible increased future generation. ICF Incorporated indicates a typical secure landfill has 25 acres of operating area with a capacity for 875,633 cubic yards (cy) (23). At an assumed specific gravity of 1.28, the Air Force's worst-case sludge production would be an estimated 14,000 cy's per year. By this estimation, one 25-acre landfill has sufficient capacity to easily accommodate all the Air Force's IWTP sludged generated during the next 57 years.

One large landfill might not be as convenient for disposal as 25 one-acre landfills, so it is necessary to consider the military's capability for having several smaller areas serving as secure landfills. In FY 1979, the DOD had 950 installations and properties in the United States, excluding Reserve centers and various minor properties. The Air Force controlled 46 percent of these facilities (34). The land area minus building area which is associated with 72 major Air Force properties is 540,110 acres (39). If each potential landfill with a single-acre operating capability were conservatively estimated to require 40 acres of supporting area to ensure the

facility is adequately remote from nearby water wells or private structures, less than 0.2 percent of the Air Force's land (without buildings) would be needed to satisfy the entire disposal requirement for the Air Force's industrial wastewater treatment sludges for well over half a century. See Appendix C for the calculations used in this determination.

This author feels it is unnecessary to make a similar estimate for the capability of the private waste disposal industry. The EPA estimates that there are at least 14,000 transporters and at least 14,000 storage and disposal facilities as of 1981 (46). Evidence of an established waste disposal industry is indicated by the existence of the National Solid Waste Management Association (NSWMA) with a membership of several thousand. NSWMA represents roughly 10,000 companies, and the average company has been in business at least 14 years. NSWMA recently formed a new group, the Liquid Waste and Sludge Transporters Council, that addresses the special handling and management needs for members wishing to enter that market (42). Appendix D contains a list of some companies active in the disposal of industrial wastewater treatment sludges.

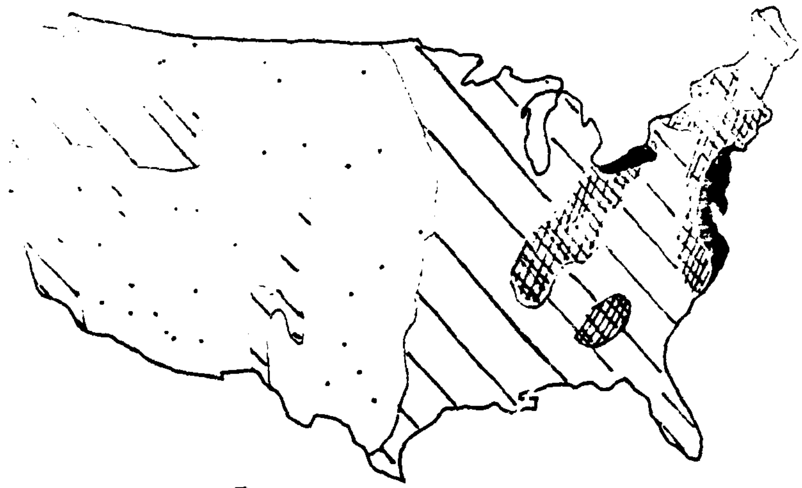
There are other physical concerns besides volume, equipment, and manpower which influence the capability for siting secure landfills in a region. These influences involve demographic, geologic, hydrographic, and climatic conditions which create the site's total environment. ICF Incorporated has initially considered some environmental influences in a zip code-area arrangement to determine the "limits" placed on

waste disposal (23). For example, JCF Incorporated used maps, which were unavailable for this study, to show the location of areas with high contamination potential due to aquifers and usable groundwater supplies within the area. Maps showing predetermined levels of population density also show areas with high or low contamination potential. Figures 4a to 4f map other physical influences which SCS Engineers, Inc. and others used to evaluate the suitability of areas for landfills. Maps covering all of the country, such as Figures 4a to 4f, are usually generalized in nature and do not show local variations. More accurate data for specific areas should be used when available.

Risk Determination

Risk is the chance that harm or loss will occur (21: 1160), and an evaluation of risk is one important ingredient in planning for hazardous waste management. This section will discuss risk evaluation and the related subjects of risk perception and risk categories.

By definition, risk exists due to the probability that an undesirable consequence may occur. At present, planners use both objective and subjective techniques to evaluate probabilities. Although several authors promote the use of objective assessments based on historical data bases (18; 23), the scarcity of sufficient historical data (18; 23; 65) requires that both the objective and subjective elements of assessment be considered in the model presented in this study.

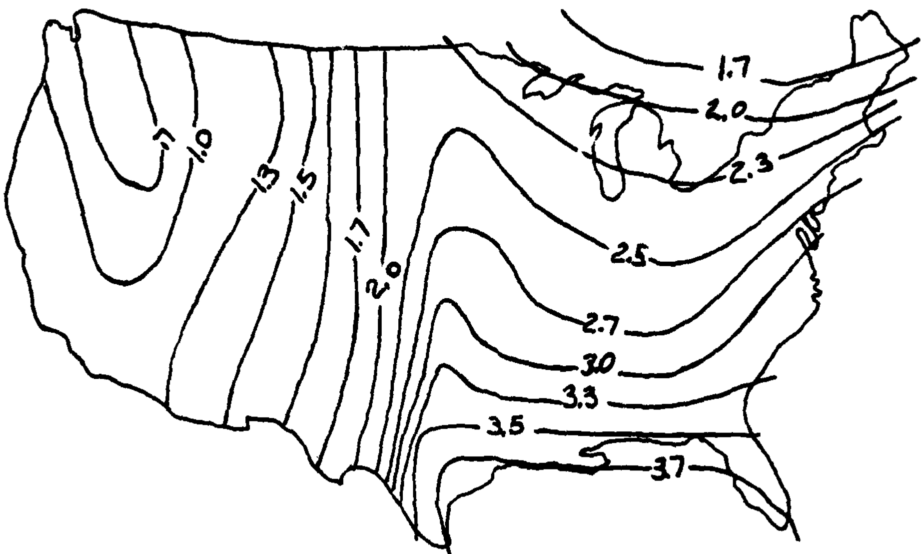


Persons per Square Mile

< 2   2-64   64-256   > 256

Fig 4a. Population Density

Source: Adapted from (40)



1 Hour - 25 Years

Fig 4b. Rainfall Frequency-Duration Data

Source: (51)

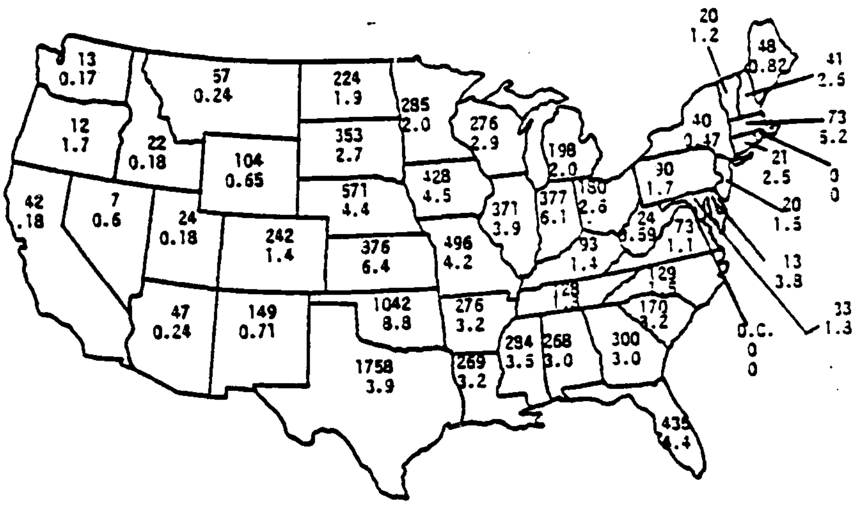


Fig 4c. Tornado Incidence (upper figure is number of tornados--lower figure is mean annual number)

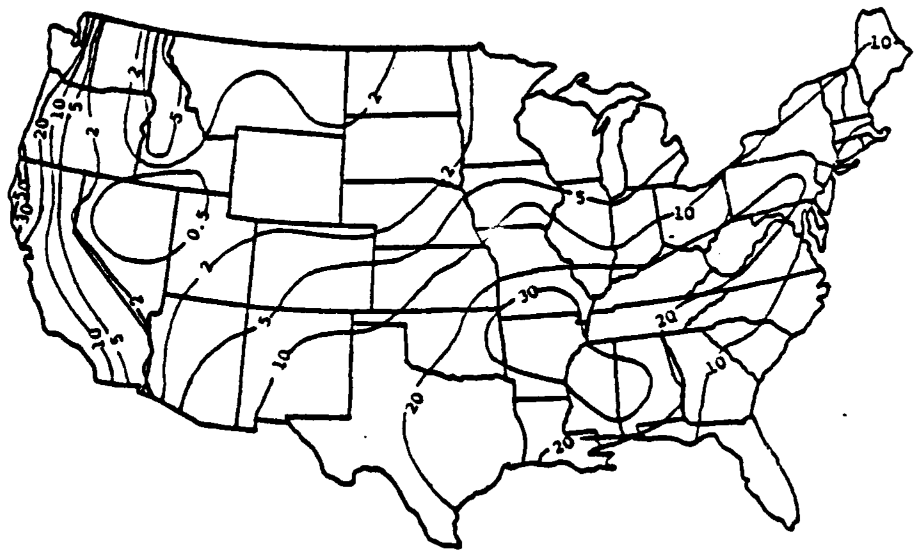


Fig 4d. Flood Potential for the Mean Annual and Ten-Year Floods

Source: (44)

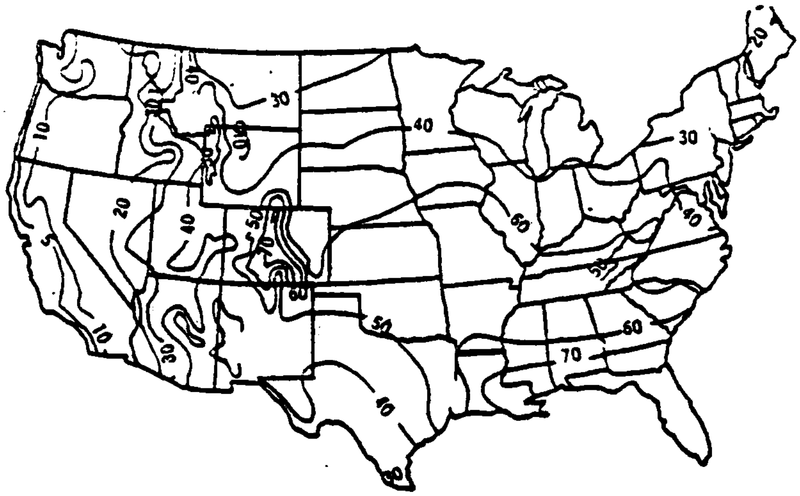


Fig 4e. Mean Annual Days Without Thunderstorms

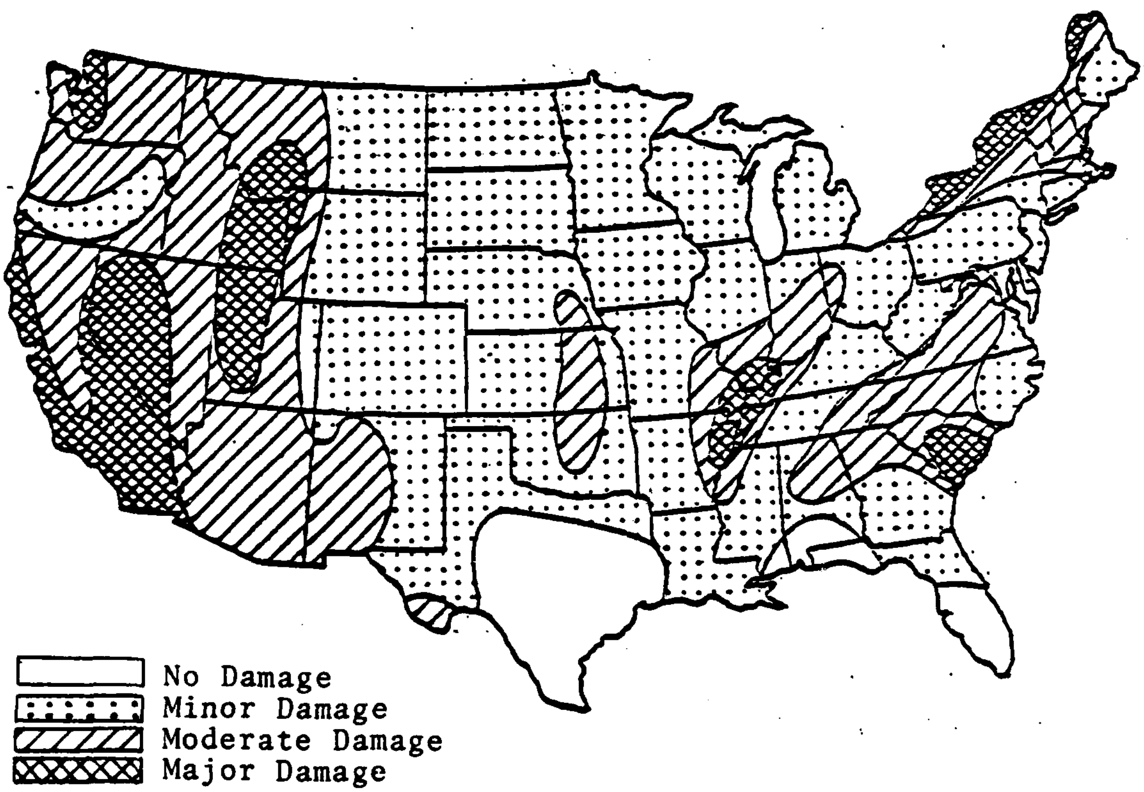


Fig 4f. Potential for Earthquake Damage

Source: (44)

In situations where historical data are available, they can be analyzed as illustrated in Figures 5a, 5b, and 5c. The resulting objective probability describes a number of similar events which Ess modeled as the sequence shown below (18):

EVENT: Hazard→Outcome→Exposure→Consequence

Example:

Liner ruptures from earthquake → Sludge elements leach into water → Person drinks water → Illness to person

Both Shih and Ess, who have together expressed the need for quantitative tools to apply to hazardous waste risk analysis, believe a promising, yet imperfect, method is to use expected utility theory with the mechanics of multivariate decision analysis. However, they acknowledge the magnitude of the problem by describing the manmade risks involving hazardous waste management as "extremely complex and uncertain" (19).

Even when historical data are not available to support objective, quantitative assessments, the literature demonstrates writers' interest in dealing with subjective or qualitative judgments with as much control as possible. Table 3 illustrates the minimum treatment of non-qualitative risk factors--a list of risk factors.

In another example, SCS Engineers, Inc. use subjective analysis to qualitatively summarize the risk values associated with land disposal as being high or low (43:28). Table 4 illustrates how SCS Engineers, Inc. matched qualitative values with different consequences.

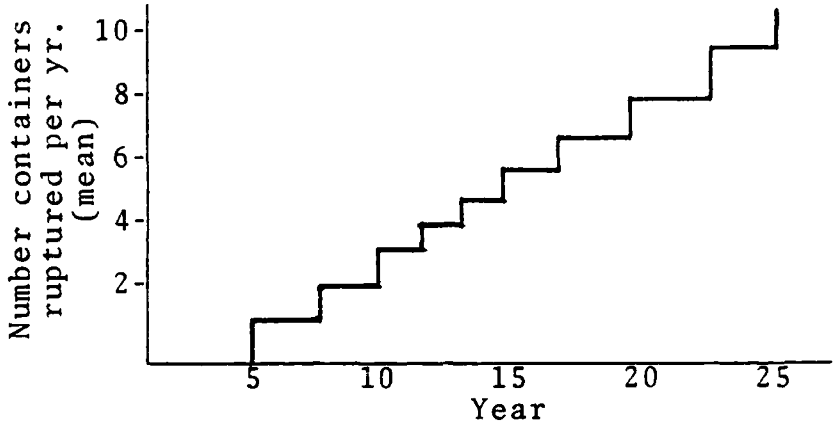


Fig 5a. Container Rupture Rate - Hypothetical

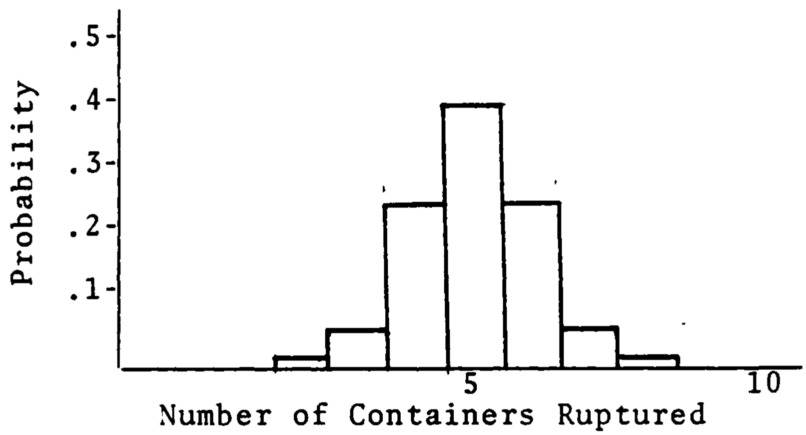


Fig 5b. Rupture Probability Function (15th yr) - Hypothetical

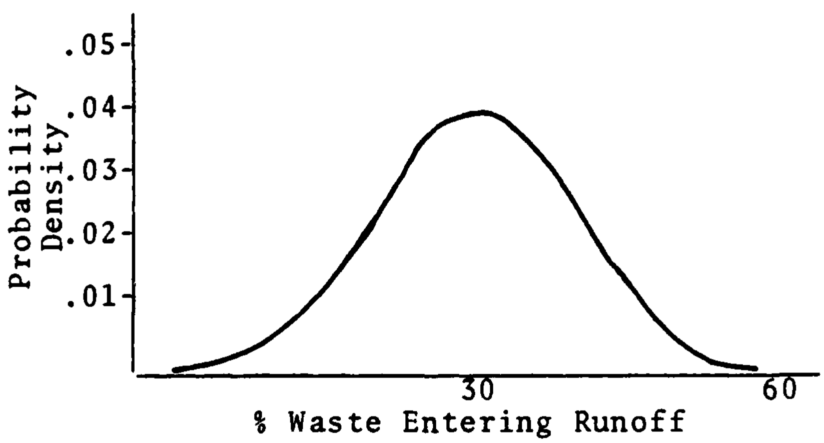


Fig 5c. Surface Runoff Contamination Probability Density - Hypothetical

Source: (18)

TABLE 3

Example of a Subjective, Non-Quantitative Assessment

Risk of Damage from Catastrophic Events for Landfills		Potential Environmental Risk Associated with Landfills	
Earthquake			
Toppling	-	Potential for health impacts	+
Fracture	-		
Floods			
Translocation	-	Potential for surface water pollution	+
Immersion	-		
Deposition	+	Potential for subsurface pollution	+
Erosion	+		
Tornadoes			
Translocation	-	Potential for air emissions	+
Vortex	-		
Impingement	-		
Fire			
Electrical	-	Ash/Sludge/Concentrate production	-
Direct Combustion	-		
Melting	-		
Explosion	-		

KEY:
- equals no or minimal impact
+ equals impact
Source: (43:236-237)

TABLE 4

Risk Summary Scheme by SCS Engineers, Inc.

Consequence	Summary of Risk Associated with Land Disposal
Catastrophic Event	LOW
Downtime	LOW
Environmental Impact	HIGH

Source: (43:28)

Another approach uses both objective and subjective analysis to assign a quantitative value to risk. Examples of this approach as shown by Shih and Ess are partially based on a classification of risks as either voluntary or involuntary (19). Voluntary risks are those associated with activities such as hunting, skiing, smoking, and general aviation--in other words, risks which an individual may choose to accept or to avoid. Involuntary risks are those which occur outside normal human choice, such as the risk of dying from a natural disease. In addition to the distinction between voluntary and involuntary risk, which was adopted from earlier theories (25; 17), the scheme described by Shih and Ess incorporates the concept of catastrophic risks (a single event harming many people) versus ordinary risks (several small events causing the same amount of harm as a catastrophic event). And finally, the schemes used by Shih and Ess include the concept of whether the risk is perceived as being fatal rather than merely injurious. According to Ess, Rowe states that humans are more willing to accept voluntary than involuntary risk, ordinary than catastrophic risk, and injurious rather than fatal risk (17).

As illustrated in Table 5, Shih and Ess matched these concepts of risk with values determined through mathematical relationships in an attempt to objectify risk analysis.

The risk calculations for the model presented in the present study incorporate the catastrophic/ordinary categories as well as an additional category labelled immediate/

TABLE 5

Possible Risk Summary Scheme

30-yr Risk Analysis for an Uncontrolled Dump Site		
Risk Classification	Objective Risk's Value Range	Risk Referent's* Value Range
Involuntary, catastrophic, fatal	$8.4 \cdot 10^{-6}$ to $7.5 \cdot 10^{-5}$	$1.0 \cdot 10^{-14}$ to $1.0 \cdot 10^{-12}$
Involuntary ordinary fatal	$7.5 \cdot 10^{-5}$ to $5.0 \cdot 10^{-13}$	$5.0 \cdot 10^{-13}$ to $5.0 \cdot 10^{-11}$
Involuntary catastrophic health	$7.5 \cdot 10^{-5}$ to $5.0 \cdot 10^{-4}$	$5.0 \cdot 10^{-14}$ to $5.0 \cdot 10^{-12}$
Involuntary ordinary health	$7.6 \cdot 10^{-4}$ to $3.3 \cdot 10^{-2}$	$3.0 \cdot 10^{-12}$ to $3.0 \cdot 10^{-10}$

*Risk Referent is derived through a combination of subjective and objective analysis
SOURCE: Adapted from (19)

future, which Shih and Ess also used (19). According to Rowe as described by Ess (17), immediate risks (those which are seen as near term or imminent) are valued higher than future risks (those which may occur in the more distant future). The classification of catastrophic/ordinary and immediate/future are used in the model to rank the events which the Air Force manager must imagine when trying to determine risks. Each imagined event of a certain condition can be assigned a subjectively derived value for all significant consequences (43:234-248; 19).

TABLE 6

Possible Scheme for Risk Determination

Nature of Consequences	Conditions of Event			
	Immediate		Future	
	Catastrophic	Ordinary	Catastrophic	Ordinary
Fatality	X	X	X	X
Morbidity	X	X	X	X
Perceived Threat of Liability	X	X	X	X
Property Damage	X	X	X	X
Operational Delay	X	X	X	X
Equipment Damage	X	X	X	X
Environmental Damage	X	X	X	X
X = a quantitative or qualitative value				

Table 6 shows the terminology for consequences identified in the literature; the table also displays the format Air Force managers can use to record their evaluation of risk from hazardous waste disposal. The decision-maker must recall events having the required conditions in order to evaluate the likelihood of a particular consequence occurring. For example, an immediate catastrophic event might be considered as the condition where a ruptured liner would occur in conjunction with severe flooding within the next three years and cause widespread exposure to released contaminants. An immediate, ordinary event might be a rupture which would expose few people to the released contaminants during the next three

years. A future catastrophic event might be imagined as the condition where a workforce strike sometime 3 to 20 years in the future disrupts the entire base's operations. A future ordinary event might be imagined as a distant strike which would cause inconvenience to isolated groups on the installation.

Costs

As the discussion of risk indicates, one approach to choosing the best alternative from among several options is to base the decision on the expected consequences. The expected consequences are sometimes expressed in monetary units which can reflect the value of sacrifices associated with each option. Grant and Ireson state that the primary criterion in a choice among alternatives should be to make the best use of limited resources, and costs are a monetary measure of the amount of resources used in an operation (22:12). Appendix E lists numerous ways in which costs are classified to aid evaluation of alternatives. The length of the list in Appendix E indicates that confusion can easily arise when managers try to decide which type of costs are practical for consideration. The purposes of this section are to explain which types of cost are appropriate for consideration and to present actual values identified in the literature.

When different options are compared, some costs will usually be identical while others are different. The costs that vary from option to option are differential costs.

"Since only differential costs are relevant to making a decision, the costs that are the same for all the alternatives can be ignored [45:566]." In addition, costs that have already been incurred because of past decisions and cannot be changed or avoided by current or future decisions (sunk costs) can also be ignored when choosing between alternatives (45:567).

Another cost, opportunity cost, is a concept which comes from economics where some value for a course of action is measured by the benefit given up by not following the next best alternative. It is an imputed cost which managers consider in order to select the alternative which maximizes economic gain (45:567). However, Anthony and Herzlinger point out that this is rarely a practical consideration for non-profit organizations (4:203). The military is both a non-profit organization and a public service organization. Grant and Ireson also point out that it is difficult to determine opportunity costs for activities involving governmental, public service organizations. They state that it is acceptable to place these costs in a category called "irreducibles." Irreducibles represent the consequences of a decision that cannot be practically expressed in monetary units for purposes of an economy study (45:471).

Differences in cost between alternatives also occur because a dollar spent at one date is not directly comparable with a dollar spent at another date. Period costs recognize the amount of money needed to establish some equivalence with monetary units spent at different times. The literature

includes various estimated interest rates to account for this time value of money. According to Grant and Ireson, decisions involving the choice of an alternative which makes the most economical use of resources,

> . . . must be based on preliminary estimates. . . that necessarily have considerable danger of large errors. For this reason great precision is not usually required[;] . . . similarly the difference between paying interest once a year and paying it more often is usually neglected in economy studies [22:44].

The interest rate used to account for time value is called a discount factor. Table 7 shows that the relative outcome in cost between disposal techniques having different patterns of cost through time is rather insensitive to varying discount rates. Note that the ratio of costs between alternatives remains similar despite the magnitude of the discount rate.

TABLE 7

Ratio of Present Value of Unit Costs

Discount Rate (%)	Double-Lined Landfill	Unlined Surface Impoundment	Ratio
1	$18.40	$5.65	.31
6	$13.50	$3.95	.29
10	$11.50	$3.15	.27

Source: (23)

Although there are many monetary values cited in the literature which relate to landfill disposal, comparison is difficult because the costs apply to different types of physical units and to different time periods. Also, the circumstances to which the costs apply are often slightly different

or not clearly defined. Despite the confusion, Arthur D. Little, Inc. has estimated that the incremental price increase for offsite disposal in secure landfills is $9.33 per metric ton as a result of RCRA (8:C-14). Arthur D. Little, Inc. also states that the typical private industry profit before taxes is 30 percent (8:C-11).

In Appendix F, specific present worth values for elements of secure landfill costs have been compiled from several studies. The costs are grouped under the following headings:

- Administrative, Reporting, Recordkeeping Costs
- Capital Cost
- Operating & Maintenance Costs
- Capital Costs at Closure
- Post Closure Care Costs
- Miscellaneous Costs

Appendix F includes differing values for the same elements to roughly indicate how much variation can occur, depending upon the source of information. For this study, the values in Appendix F are used as a starting point to derive the costs necessary to perform the economic analysis in the decision model.

Three confounding matters make some of the data in Appendix F unreliable for estimating costs when making comparisons with bidders' proposals: 1) the data are compiled on secure landfills that are located in different areas of the country; 2) the landfills vary in size from 1 acre to 50 acres; and 3) different interest rates were used by different sources

to incorporate the time value of money. These problems were circumvented since the purpose of the economic analysis within this study is not to establish a current price which can support government estimates during the procurement process. Rather, the purpose is to determine the relative economic advantage which one option has over another. Thus, this study takes advantage of the pricing convention which holds that alternative costs for alternative options can be treated as though the costs vary proportionally over time and between regions. Used in this way, the present values in Appendix F provide a convenient standardization for comparison.

Also, when available, the cost distinctions between different scales of operation are identified. This treatment makes a comparison feasible since the ratio of costs can be estimated although the magnitude of amounts may actually vary.

CHAPTER III

A DECISION MODEL

Some difficulty associated with choosing between alternative disposal arrangements is attributable to the varying types and amounts of empirical data available for evaluating physical limitations, cost, potential liability, risk, and policy. The author's proposed decision model addresses this difficulty by using three analytical methods in sequence to accommodate varying types and amounts of available empirical data. (See Figure 6.) The rationale used in developing the procedure for a site analysis, an economic analysis, and the risk analysis is explained through the rest of this chapter.

Site Analysis

The first method in the sequence is an analysis of the suitable land area available for a contractor's disposal facility and the suitable land area available for a military facility. The purpose of this analysis is to determine the location for military and civilian landfills which have comparable attributes. The important attributes for this study are that: 1) both sites have the capability to accommodate wastes for a selected minimum period of time; and 2) both sites have comparable physical conditions that are conducive to safe, stable operations. Sites having the first attribute will help the manager ensure that either choice has the desired degree of

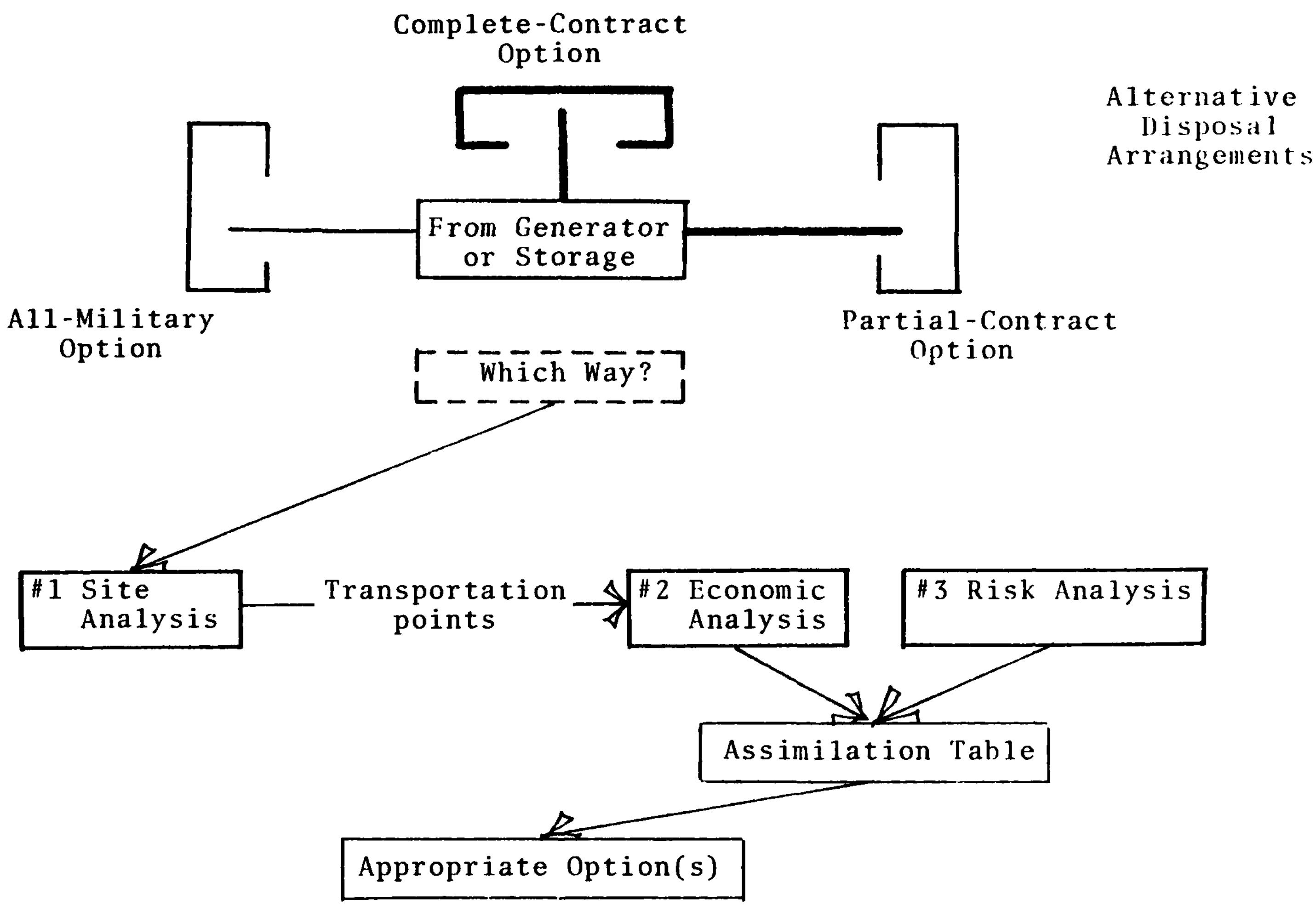


Fig 6. The Basic Decision Model Relationships

permanence. The following calculations are proposed by the author to determine the minimum required operational areas for a contractor's facility (CA_{op}) and for a military facility (MA_{op}).

$$CA_{op} = \frac{\text{Tons of Civilian Waste + Tons of Military Waste}}{\text{Tons of Waste Disposed per Acre}}$$

$$CA_{op} = \frac{SF \cdot DP((\frac{pop \cdot rate}{2000}) \cdot \text{tech reliance fac}) + \text{base}}{36{,}600}$$

$$MA_{op} = \frac{\text{Tons of Military Waste}}{\text{Tons of Waste Disposed per Acre}}$$

$$MA_{op} = \frac{DP \cdot \text{base}}{36{,}600}$$

where:

CA_{op} = contractor's minimum required operational area in acres

MA_{op} = military's minimum required operational area in acres

SF = safety factor to account for a 6% per year population growth for 20 years. A factor of 3 is used for this study and is derived from the compound amount factor where $(1+i)^n = 1.06^{20} \approx 3$ (22:607).

DP = the desired number of years for which the decision-maker intends to rely upon the disposal facility. This study uses 20 years for the desired period because the cost data in Appendix F are based upon a 20-year operating life.

pop = civilian population served by the disposal facility

tech reliance fac = the technical reliance factor which represents the extent to which secure landfills are relied upon by the civilian population. This study uses a value of 0.7 as estimated from an EPA study of industries (7:7).

base = the amount of the military base's waste for the landfill in tons per year as determined from manifest records.

rate = 550 pounds per person per year as derived from EPA estimated hazardous waste generation for the United States in 1980 (5; 40:ix).

void cap = the portion of the landfill void which is actually occupied by hazardous wastes. See Appendix G. The value used in this study is 0.7 (23).

depth = 30 feet. This allows 15 feet of fill above the existing elevation and 15 feet of excavation into the site. This depth comes from the author's defined reference for a secure landfill as shown in Figures 3a, 3b, and 3c. A subsequent 6-foot cap and even grading from the berm to the outer edge of the support zone would result in a slope of 10.5 percent. Such a landform would be relatively unobtrusive, ensure adequate drainage without unduly disrupting revegetated areas, and perhaps still serve some follow-on use of a recreation site. A return of the site to its exact original configuration is not wanted because the author believes it is advisable to have the area retain some subtle difference so the exact area of burial may be kept obvious in the absence of recorded survey information.

43,560 = square feet in one acre.

27 = conversion factor for changing cubic feet into cubic yards.

conv fac = conversion factor for changing cubic yards into estimated tons. This study uses a value of 1.08 tons per cubic yard (14).

36,600 = the approximate tons per acre for a landfill having a depth of 30 feet and a void capacity of 0.7 as determined by the following:

$$[(43{,}560 \cdot \text{depth} \cdot \text{void cap}) \div 27] \cdot \text{conv fac}$$
$$= [(43{,}560 \cdot 30 \cdot 0.7) \div 27] \cdot 1.08$$

The total minimum acres required for future disposal is a combination of the operational and support areas. The author's proposed definition for this is derived from the following relationship:

relationship:

$$CA_{op+sup} = \frac{(\sqrt{CA_{op} \cdot 43,560} + 520)^2}{43,560}$$

$$MA_{op+sup} = \frac{(\sqrt{MA_{op} \cdot 43,560} + 520)^2}{43,560}$$

where:

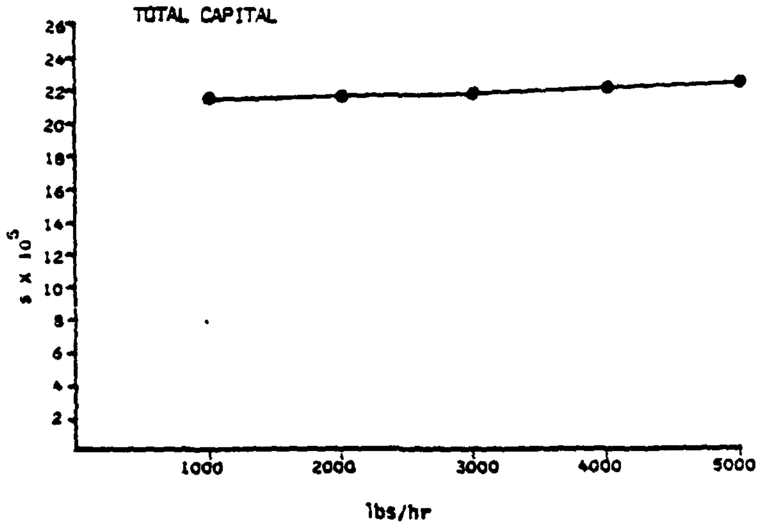
MA_{op+sup} = total minimum required acres for a military facility

CA_{op+sup} = total minimum required acres for a contractor's facility

520 = the length of the buffer zone from the operational area to the boundary of the facility. This area could contain the facility's office structure, vehicle shelters, fencing, a rinse system, and the access road. This dimension comes from the reference secure landfill which the author defined in Figures 3a, 3b, and 3c. This buffer zone also provides sufficient area to create an even 10.5% slope from the berm to the edge of the support zone.

Some minimum for MA_{op} would be beneficial from the standpoint of achieving greater economy with larger scale (22:95). Figures 7a, 7b, and 8 suggest the extent of economy found in larger facilities.

After the calculations are complete, the minimum required areas for operation and support (MA_{op+sup} and CA_{op+sup}) can be compared with maps showing the adequate available area at both sites. The adequate available areas on the map are determined by eliminating from consideration those areas where physical hindrances may disrupt a stable landfill operation. Zones with the following unwanted physical influences are identified on the map to make the elimination.



Disposal Rates Equated to Lifetime
Capacity of Facility

1000 lbs/hr = 20,800 tons

2000 lbs/hr = 41,600 tons

3000 lbs/hr = 62,400 tons

4000 lbs/hr = 83,200 tons

5000 lbs/hr = 104,000 tons

Fig 7a. Changes in Total Capital Costs with Scale for Landfills (44:218)

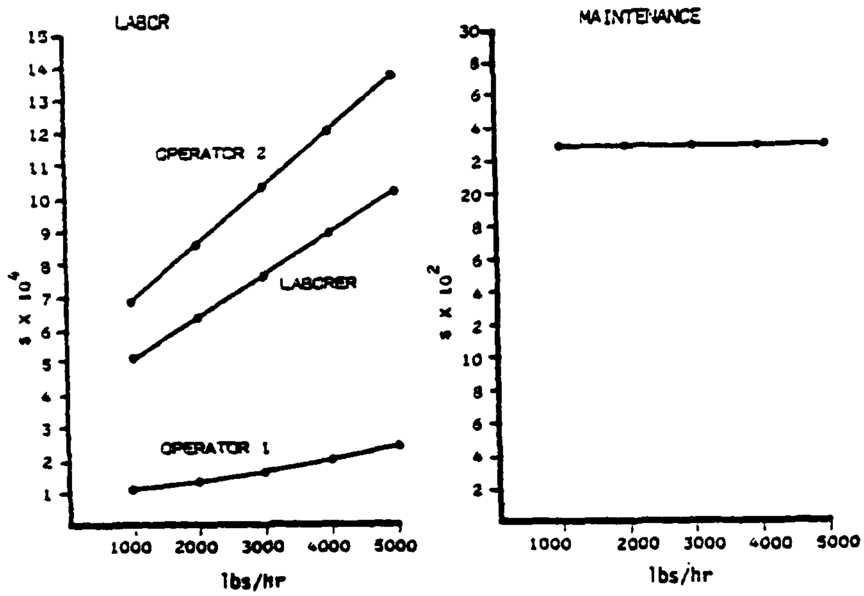


Fig 7b. Changes in O&M Requirements with Scale for Landfills (44:220)

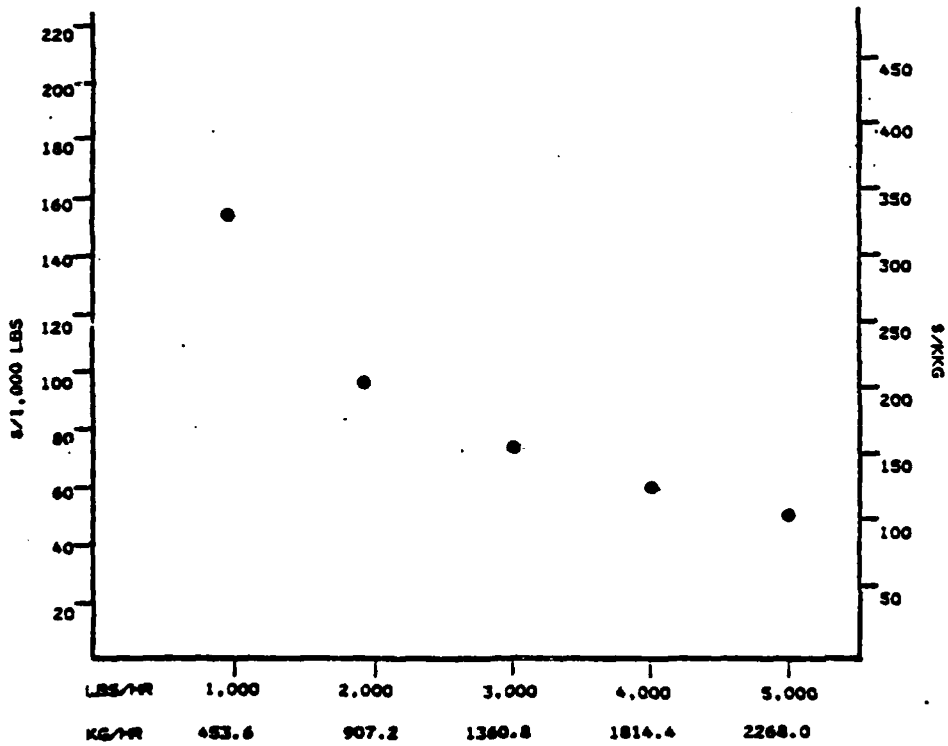


Fig 8. Life Cycle Costs with Scale of Operation for Landfills (44:222)

1. Zones with a population density exceeding 26 persons per square mile based upon an area extending 30 miles from the prospective site. This criterion is applied to avoid public pressure and resentment. The arbitrarily chosen density is intended to represent a remote area; however, a more or less stringent standard may be appropriate.
2. Zones having special historic value or having special scenic value to regional inhabitants (51:2-4).
3. Zones along active earthquake fault lines (see Appendix A) (Title 40, Part 264).
4. Zones having a history of rockslides or mudslides. This criterion is applied to avoid locations where the operating life of the landfill would be placed in peril, the lining system might be ruptured, or the location of the facility might shift.
5. Wetland zones (51:2-4).
6. Zones within a 100-year floodplain (see Appendix A, Title 40, Part 264).
7. Zones needed to support endangered species (51:4).
8. Zones where the highest groundwater elevation is within 25 feet of the existing surface elevation. This criterion is more conservative than EPA policy (54:11). This criterion is applied to avoid the added expense for establishing wellpoints during construction and to minimize the chances of water becoming a transport medium when wastes are released. Other groundwater

elevation points are possible depending upon the depth used for the reference landfill.

9. Zones where the soil permeability is 10^{-7} cm/sec or more. This criterion is applied to enable use of the indigenous soil as the secondary liner (thus reducing construction costs) and to locate wastes in areas where the native soils act as an additional barrier. Again, the author is advocating a policy which is not essential, but it offers extra protection and reduces construction costs (10; 54:21).

After areas which meet the above criteria are excluded, the remaining areas represent the adequate available land which exists under similar, safe physical conditions. For purposes of this study, available land refers to land which has an unused disposal capacity and is under the DOD's or contractor's control. The prospective remaining available areas must be at least equal to CA_{op+sup} and MA_{op+sup} in order to be considered adequate. The resulting adequate areas have characteristics that surpass minimum federal requirements and will determine the destination points upon which transportation costs will be based.

Figures 9a and 9b illustrate the site analysis method under hypothetical circumstances. Note that the nearest sites with their accompanying transportation routes are chosen for the economic analysis. This selection does not exclude either the contractor's or DOD's other potential sites from later consideration. Rather, it serves to identify for comparison

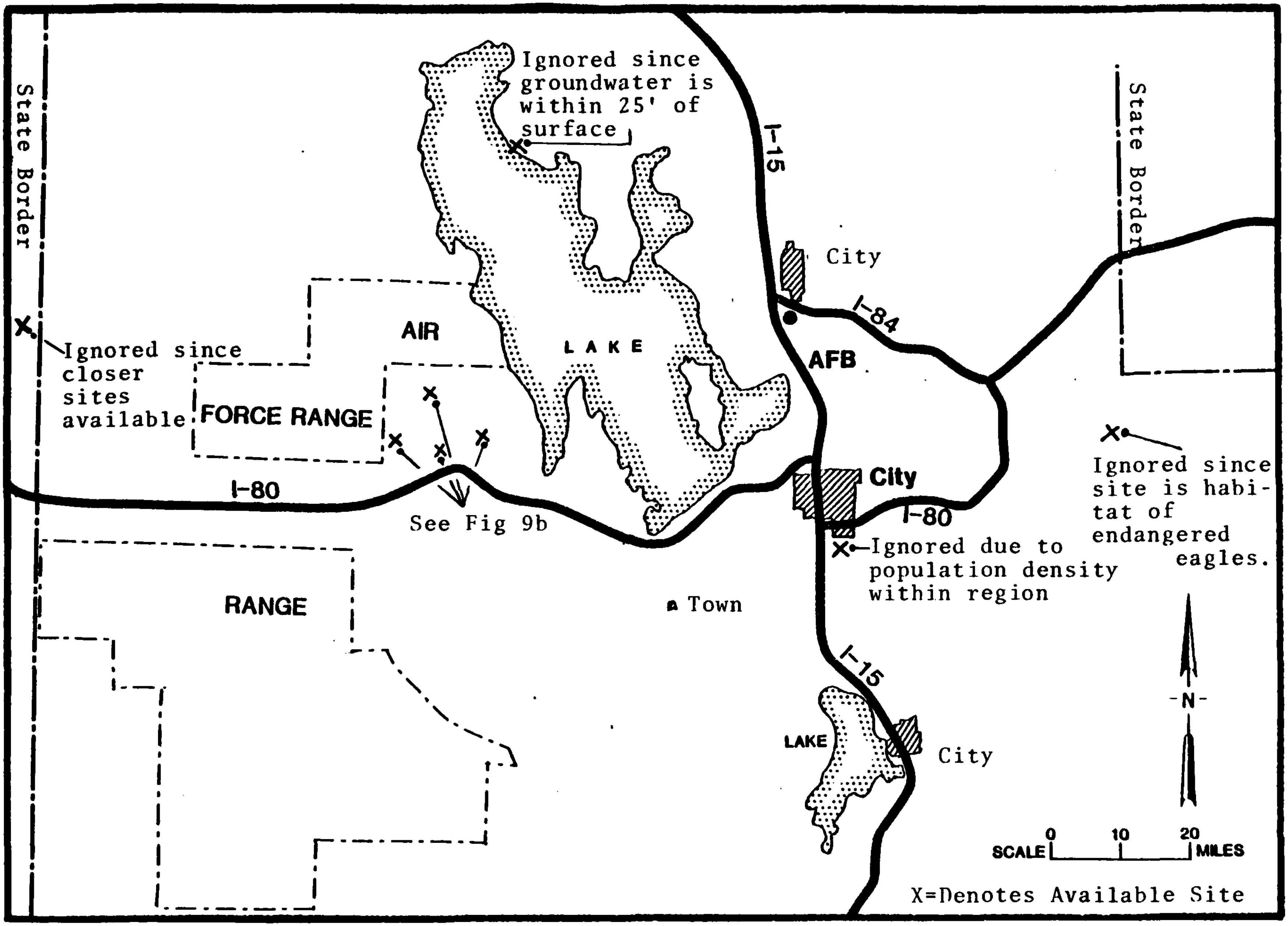
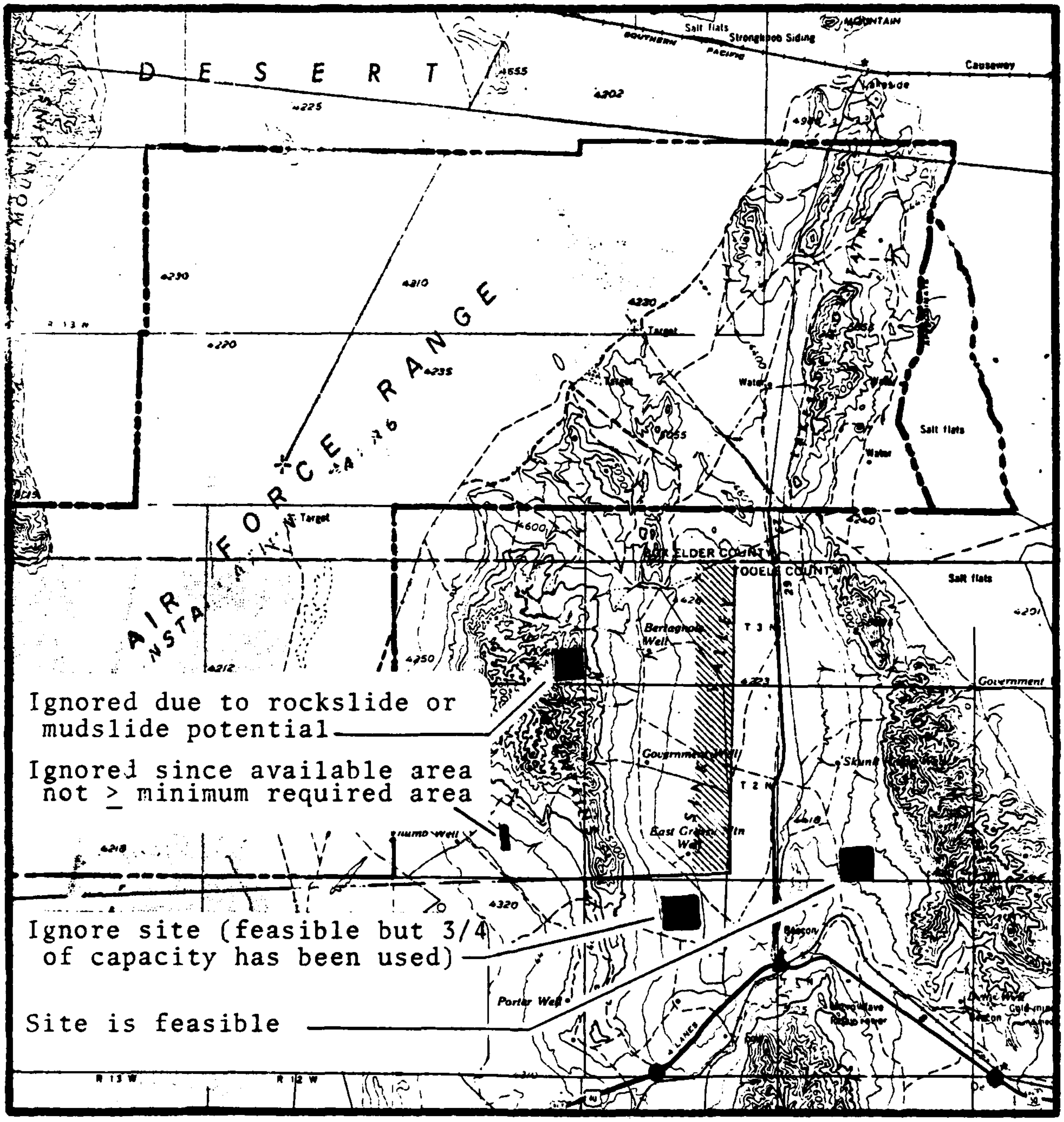


Fig 9a. Hypothetical Site Analysis



Note: 1. Scale 1" = 5 miles
2. Minimum required area equals ■
3. Site conditions must be verified through field checks and inspection.

Fig 9b. Hypothetical Site Analysis

existing sites having common features.

Economic Analysis

The second method in the sequence is an economic analysis of each disposal option for 20 years of operation and 30 years of post closure care and monitoring. The 20-30 combination was chosen because it corresponds to the time periods used in deriving the present worth cost data contained in Appendix F. The economic comparison is made by extracting cost values in Appendix F for compilation according to the author's proposed format which is identified in Table 8.

The cost data and computations rely upon some assumptions which should be recognized. These assumptions are: 1) the wastes are transported to the landfill by a roadway vehicle; 2) the military landfill is constructed by a civilian contractor who does not get paid at overtime rates; 3) the cost of constructing a secure landfill will be identical for both the Air Force and the business organization; 4) the waste generation rate does not change; 5) cost increases at a constant rate over time; and 6) cost changes proportionally between regions. The rationale for deciding what amount of cost difference is significant for classification comes from the executive policy for justifying contract performance.

It is executive policy that,

> in-house activity will not be converted to contract performance on the basis of economy unless it will result in savings of at least 10% of the estimated Government personnel costs for the period of the comparative analysis [20:9].

TABLE 8

Format for Economic Analysis

Cost Element	Complete-Contract Option (C)	Partial-Contract Option (PC)	All-Military Option (AM)
One Time Admin, Recordkeeping Recording (Present Worth)			
Set up of system			
Waste Analysis Plan			
Post Closure Plan			
Application for permit & maint. of permit (twice)			
Contingency Plan			
Transportation report & application for ID			
Provide financial assurance for post closure			
1st Year Immediate Capital Costs (Present Worth)			
Land			
Equipment			
Building			
Communication system			
Rinse system			
Synthetic liner			
Clay liner			
Excavation			
Berms			
Leachate collection			
Monitoring Wells			
Fencing			

TABLE 8, continued

Cost Element	Complete-Contract Option (C)	Partial-Contract Option (PC)	All-Military Option (AM)
1st Year, cont.			
Access Roads			
Surface Water diversion			
Revegetation			
Geotechnical & hydrological testing			
Yearly Admin, Recordkeeping, & Reporting (Present Worth)			
Disposal report to EPA			
Manifest Handling signing, preparation			
Recordkeeping of manifests, reports			
Training Records			
Training Costs			
Inspection & Review of regulations			
Transporter recordkeeping			
Contract administration			
10th Year Replacement Capital Costs (Present Worth)			
Equipment			

TABLE 8, continued

Cost Element	Complete-Contract Option (C)	Partial-Contract Option (PC)	All-Military Option (AM)
20th Year Capital Cost at Closure (Present Worth)			
Synthetic Cover			
Clay Cover			
Revegetation			
Annual Operations & Maintenance (Present Worth)			
Personnel			
Fuel & Maint.			
Utilities			
Collection & analysis of groundwater			
Testing & analysis of waste			
Lump Sum Unit cost			
One Time Post Closure Care Cost (Present Worth)			
Decontamination & decommissioning			
Annually			
Perpetual monitoring			
Miscellaneous			
Profit			
Transportation			
TOTAL			

The application of this criterion is illustrated with the following set of assumed costs:

Option	Total Personnel Costs	Savings
All-Military (AM)	$20,000	
		$1,000
Partial-Contract (PC)	$19,000	
		$4,000
Complete-Contract (C)	$15,000	

Criterion of significant difference = 10% of $20,000 = $2,000

$1,000 < $2,000; thus AM and PC have similar costs

$4,000 > $2,000; thus C is significantly different

The results of the above cost compilations are used to classify AM and PC as "2L" because they are the two options which tied for lowest preference. C is classified as "MP" because it is most preferred among all three hypothetical examples. Other possible classifications are described below:

L = least preferred among all options

S = same preference among all options

M = mid-preference, where the option is neither most preferred nor least preferred

2H = among the options which tied for highest preference

In real applications, the derived categories are later combined with similar categories from the third analytical method, risk analysis.

Risk Analysis

The third method in the sequence involves judging the relative amount of risk associated with each disposal arrangement for IWTP sludges. An individual, subjective determination is deemed most appropriate because of the scant historical

data base available for objective evaluations. The subjective determination is aided by a weighted risk matrix using the ideas described in Chapter II. See Table 9 for an example of a partially completed matrix applicable to IWTP sludges. A similar weighted matrix will be used to derive a score for each disposal option. Table 9 shows the rank of importance assigned by the author to each row and column for demonstrating the process. Different rankings might be assigned by other evaluators on the basis of their own judgment. Similarly, a value representing subjective opinion will be placed wherever an "X" occurs to represent the relative amount of risk estimated in imagined events causing the listed consequences when the options are compared.

For example, a workforce strike 15 years from now would not likely disrupt an entire base. Such an event fits the future ordinary condition (see Table 9), and its expected consequence might be operational delay within one or two organizations on base. The probability of this imaginable event causing operational delay is greater under the complete-contract option than under the all-military option because military and federal civil service employees are not permitted to strike. The value substituted for "X" would be lower for the all-military option (e.g., 1), highest for the complete-contract option (e.g., 5), and perhaps midway for the partial-contract option (e.g., 3). Using this single event as an example, the score would be computed as shown following Table 9.

TABLE 9

Format for Subjective Risk Analysis of Options
Waste Type: IWTP Sludges

Nature of Consequences	Immediate		Future		Sum of Products
	Rank = 4 Catastrophic	Rank=2 Ordinary	Rank = 3 Catastrophic	Rank = 1 Ordinary	
Fatality Rank = 3	0	0	0	0	--
Morbidity Rank = 3	0	0	0	0	--
Perceived Threat of Liability Rank = 2	X	X	X	X	--
Property Damage Rank = 2	N/A	X	N/A	X	--
Operational Delay Rank = 2	N/A	X	N/A	X	--
Equipment Damage Rank = 2	N/A	X	N/A	X	--
Environmental Damage Rank = 1	N/A	0	0	0	--
				Total Score for single option	--

Weight: X = 0 if all options judged similar
= N/A if combined event and consequence is not envisionable
= some value in range of 1 to 5; "1" represents less risk as compared to "5" representing most risk

All-Military Option

Operational Delay Rank = 2	•	Immediate Ordinary Event Rank = 2	•	Substituted Weight e.g., 1	=	Product 4

Since no other events are being evaluated for this option, the total score equals 4.

Partial-Contract Option

Operational Delay Rank = 2	•	Immediate Ordinary Event Rank = 2	•	Weight e.g., 3	=	Product 12

Since no other events are being evaluated for this option, the total score equals 12.

Complete-Contract Option

Operational Delay Rank = 2	•	Immediate Ordinary Event Rank = 2	•	Weight e.g., 5	=	Product 20

Since no other events are being evaluated for this option, the total score equals 20.

Example Summary of Scores

All-Military Option (AM)	= 4 most preferred (MP)
Partial-Contract Option (PC)	= 12 mid-preference (M)
Complete-Contract Option (C)	= 20 least preferred (L)

As with cost, where the lowest value is most preferred, the lowest value for risk is most preferred.

Assimilating the Preferences for Risk and Economy

The survey points out that the secure landfill disposal technique incurs costs due to requirements imposed by law/ regulation/policy. Furthermore, both RCRA and Air Force policy encourage a consideration of costs in waste management. For these reasons, cost is a significant influence, and the economic analysis was devised to facilitate comparisons between the disposal options.

Legislation/regulation/policy impose another general class of considerations involving possible adverse consequences that are sometimes alluded to as either risks or hazards. Both RCRA and AF policies exist for the purpose of minimizing certain potential consequences which, as yet, have not been widely translated into monetary terms. For these reasons, certain possible consequences are considered a significant influence, and the risk analysis scheme was devised to facilitate a comparison between disposal options.

The appropriateness of each disposal arrangement is dependent upon the results of the economic and risk analyses. An assimilation table (Table 10) is proposed to link the preference for risk and economy during the period in which risks are not translatable into monetary terms. Table 10 operates by matching conditions under the following policies adopted for this study.

1. Options having a combination of the most preferred (MP) risk and most preferred cost should be selected over all

other options.

2. Options having a combination which includes a least preferred (L) risk or cost should be dropped from consideration.

3. Options having costs that are tied for highest preference (2H) are acceptable if the risk is: 1) most preferred (MP); 2) among the two equal, highest preferred (2H); or 3) identical for all options (S). The reverse situation is also applied.

4. Any option is acceptable if equal preference (S) exists in both the risk and cost analysis.

5. Options having a combination of both risk and cost, both of which are in the lowest preference group (2L), are dropped from consideration.

Since this study does not determine a particular monetary value for risk, the amount of tradeoff between risks must be subjectively determined. The above policies reveal a willingness to disregard these differences as long as the assimilated cost preference is rated equal (S) or in the highest preference group (2H). Judgment is waived where options have a mid-preference (M) rating for risk in combination with mid-preference or higher (M, S, 2H, MP) for cost. Judgment is also waived where risk in the lowest preference group (2L) is matched against the most preferred (MP) or the highest preference group (2H) for cost. The option where a least preferred group rating (2L) was combined with mid-preference or equal ratings was also dropped from consideration because a remaining

TABLE 10

Assimilating the Preferences for Risk and Economy

ECONOMY	RISK: MP	2H	S	M	2L	L
	"Complete Contract Option (C)"					
MP	C	ok	ok	?	?	No
2H	ok	ok	ok	?	?	No
S	ok	ok	ok	?	No	No
M	?	?	?	?	No	No
2L	?	?	No	No	No	No
L	No	No	No	No	No	No
	"Partial Contract Option (PC)"					
MP	PC	ok	ok	?	?	No
2H	ok	ok	ok	?	?	No
S	ok	ok	ok	?	No	No
M	?	?	?	?	No	No
2L	?	?	No	No	No	No
L	No	No	No	No	No	No
	"All Military Option (AM)"					
MP	AM	ok	ok	?	?	No
2H	ok	ok	ok	?	?	No
S	ok	ok	ok	?	No	No
M	?	?	?	?	No	No
2L	?	?	No	No	No	No
L	No	No	No	No	No	No

ok = appropriate disposal arrangement
 ? = uncertain
No = not appropriate for a disposal arrangement

option with a more favorable combination of traits must necessarily exist.

The rationale for the preceding rests on the author's belief that ultimate favor in these marginal areas should be based on a clearer understanding of risk in monetary terms. Regardless, the policies adopted for this study can serve as a basis for initial consideration.

CHAPTER IV

AN APPLICATION OF THE MODEL

In this chapter the usefulness of the model will be demonstrated by applying the procedure to Hill AFB's IWTP sludges so as to determine whether the waste should be disposed in a secure landfill on DOD property or in a secure landfill on private property.

Unlined landfills have been used for disposal of IWTP sludges on military property for several years at Hill AFB (49:4-18 to 4-23). One site which is located approximately six miles south of Lakeside at the Utah Test and Training Range (UTTR) has been active since 1977 (see Figure 10a). Until recently, this landfill was the only recognized hazardous waste landfill within Utah (49). Several costs associated with meeting EPA criteria have been incurred by the military, and thirty years of monitoring is required because of past disposal practices. The continued operation of a landfill in this area is not expected to be as expensive as establishing a completely new site, since some investment has already occurred.

United States Pollution Control Incorporated (USPCI) began operating Utah's first commercial hazardous waste recovery and surface disposal site during March 1982. The USPCI site provides secure landfill disposal capability on private

land which is approximately 80 miles southwest of Salt Lake City (32). The USPCI site is about 26 miles from the military's site (see Figure 10b).

Options available to managers at Hill AFB for disposal of the IWTP sludges include: use of the USPCI site and services (the complete-contract option); use of the military site with contracted services (the partial-contract option); or use of the military site with DOD services (the all-military option). The proposed decision model is used in the following manner to determine the appropriate choice between these two available sites.

Site Analysis

Step #1: Select the nearest military/contractor's sites for comparison. In this case, the USPCI and UTTR sites are nearest. Determine the amount of suitable, unused land area (at the sites) which is available for a landfill (see Figures 10a and 10b). Since neither the USPCI site nor the UTTR site has acreage with unwanted physical criteria, the USPCI site has a usable total of 640 acres; the UTTR site has over 50 usable acres (14; 32).

Step #2: Determine the required minimum operational area for both the available contractor's site (CA_{op}) and the available military site (MA_{op}).

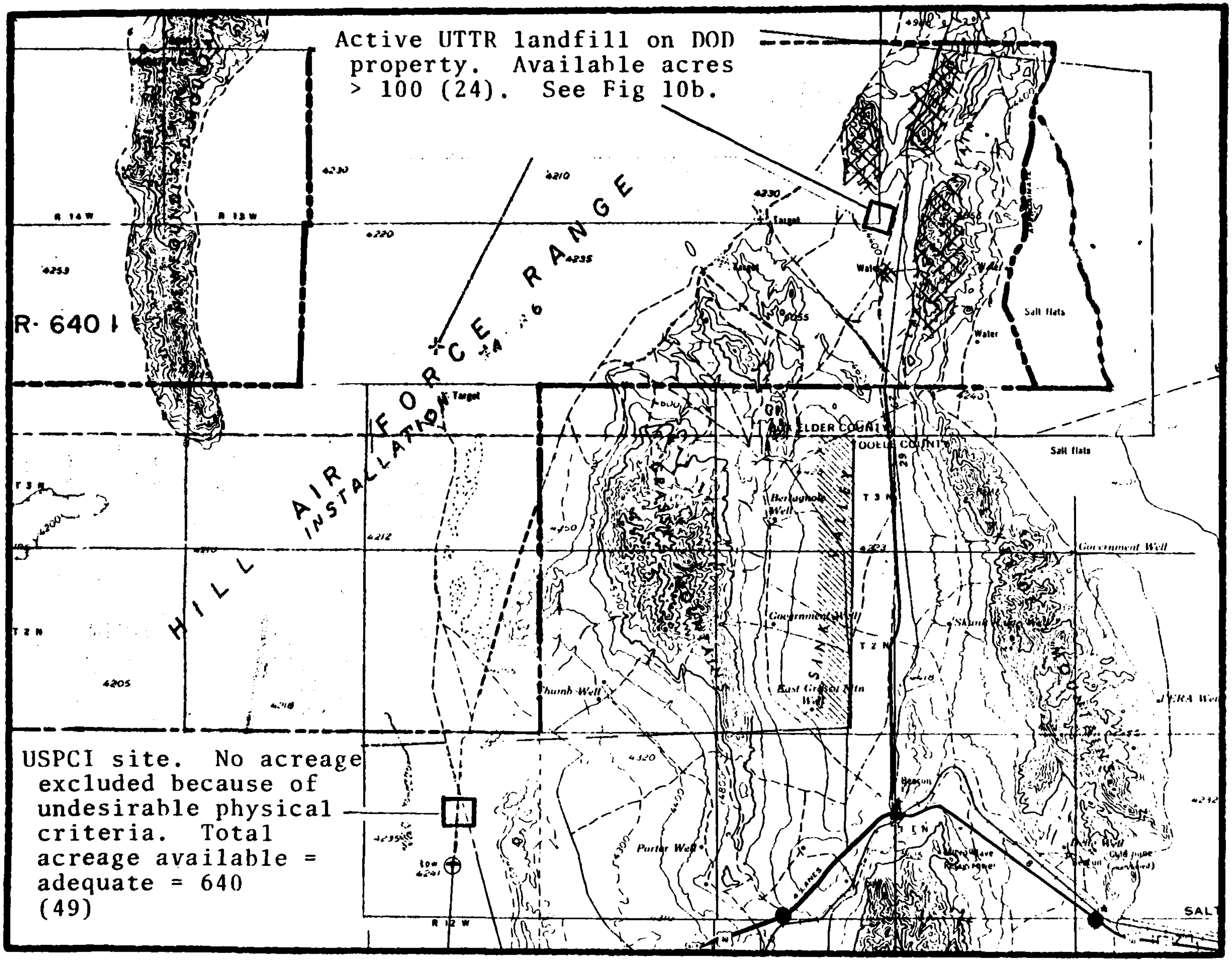
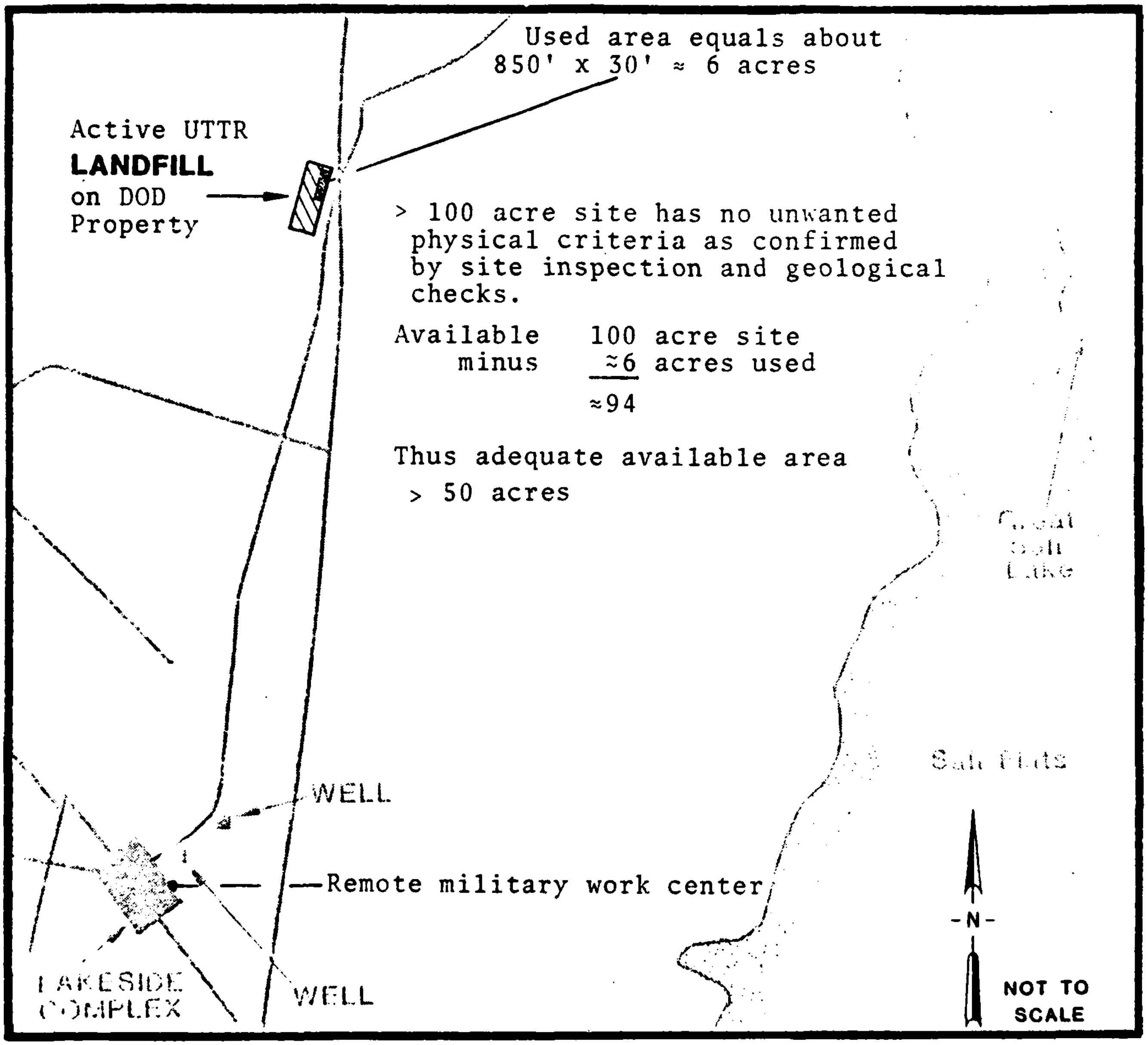


Fig 10a. Site Analysis - Military and Private
(Scale 1" = 5 Miles)

Source: (24; 32; 49)



Unwanted Physical Criteria	Excluded acreage
Population density > 26 per sq mile	0
Groundwater within 25 ft	0
Soil permeability > 10^{-7} cm/sec	0
Wetland or 100-yr floodplain	0
Earthquake or landslide area	0
Special scenic or historical significance	0
Essential for endangered species	0

Source: (24; 49)

Fig 10b. Site Analysis - Military
(for AM or PC options)

$$CA_{op} = \frac{SF \cdot DP((\frac{pop \cdot rate}{2000} \cdot \text{tech reliance fac}) + base)}{36{,}600}$$

$$CA_{op} = \frac{3 \cdot 20((\frac{1{,}461{,}037 \cdot 550}{2000} \cdot 0.7) + 657)}{36{,}600}$$

Note:

pop = 1,461,037 - state population for 1980 (40:ix)

base = 657 tons/year. Reference Hill AFB's manifest records from January to 2 July 1982 (14). The average generation rate is 54.71 tons/month.

CA_{op} = 460 acres

$$MA_{op} = \frac{DP \cdot base}{36{,}600}$$

$$MA_{op} = \frac{20 \cdot 657}{36{,}600}$$

MA_{op} = 0.36 acres ≈ 0.4 acre

Step #3: Determine the respective total minimum required acres for operations and support functions.

$$CA_{op+sup} = \frac{(\sqrt{CA_{op} \cdot 43{,}560} + 520)^2}{43{,}560}$$

$$CA_{op+sup} = \frac{(\sqrt{460 \cdot 43{,}560} + 520)^2}{43{,}560}$$

$CA_{op+sup} \approx$ 580 acres

$$MA_{op+sup} = \frac{(\sqrt{MA_{op} \cdot 43{,}560} + 520)^2}{43{,}560}$$

$$MA_{op+sup} = \frac{(\sqrt{0.4 \cdot 43{,}560} + 520)^2}{43{,}560}$$

$MA_{op+sup} \approx$ 10 acres

Both the USPCI site and the military site have at least the minimum required area available (see Table 11).

TABLE 11

Site Analysis Summary

Site	Total Available Area	Total Needed Area
[illegible]	640 acres	580 acres
UTTR	>50 acres	10 acres

Steps 1 through 3 show that the nearest available sites are located where the physical conditions are both comparable and satisfactory, and they have the needed capacity for the decision period. Had these conditions not been met, other locations would be evaluated until satisfactory sites were found.

Step #4 is to measure the distance from Hill AFB to each site: from Hill AFB to USPCI is 120 miles; and from Hill to the military site is 109 miles.

Economic Analysis

Step #5 is to compare the cost. Table 12 reveals costs as estimated from the current and present worth values provided in Appendix F. Appendix H contains the calculations supporting the estimated costs.

The totals resulting from the economic analysis are compared to determine if the personnel costs between disposal arrangements are significantly different. Totals from Table 12 reveal that the cost for the complete-contract optio is about equal to the cost of the all-military option at Hill AFB despite sunk costs benefitting the all-military option.

TABLE 12

50-Year Economic Analysis
(20-yr Operating Life)

Cost Element	Complete-Contract Option (C)	Partial-Contract Option (PC)	All-Military Option (AM)
One Time Admin., Recordkeeping Recording: (Present Worth)			
Set up of system	in unit fee	insufficient data	$695
Waste Analysis Plan			Sunk Cost
Post Closure Plan			$715
Application for permit & maint. of permit (twice)			Sunk Cost
Contingency Plan			$675
Transportation report & application for ID			$65
Provide financial assurance for post closure			Not required
1st Year Immediate Capital Costs (Present Worth)			
Land		Sunk Cost	Sunk Cost
Equipment		Insuf. Data	Sunk Cost
Building		Insuf. Data	Sunk Cost
Communication system		$500	$500
Rinse System		$10,000	$10,000
Synthetic Liner/ Clay Liner		$268,538	$268,538
Excavation		$99,372	$99,372
Berms		$186,900	$186,900
Leachate Collection		$11,347	$11,347
Monitoring Wells		$12,000	$12,000
Fencing		$19,100	$19,100
Access Roads		$7,920	$7,920

Table 12, continued

Cost Element	Complete-Contract Option (C)	Partial-Contract Option (PC)	All-Military Option (AM)
Surface Water diversion		$4,480	$4,480
Revegetation		$5,934	$5,934
Geotechnical & Hydrological testing		Sunk Cost	Sunk Cost
<u>Admin., Record-keeping & Reporting</u> (Present Worth)			
Disposal report to EPA			$1,340
Manifest Handling, signing, preparation	in unit fee		$6,050
Recordkeeping of manifests, reports			$2,200
Training Records			$2,560
Training Costs			$9,000
Inspection & Review of Regulations			$11,370
Transporter recordkeeping		insufficient data	$2,560
Contract administration	$53,300		$132,557 (for construction of landfill)
<u>10th Year Replacement Capital Costs</u> (Present Worth)			
Equipment			$10,000
<u>20th Year Capital Cost at Closure</u> (Present Worth)	in unit fee		
Synthetic Cover/ Clay Cover			Already included in initial liner cost

Table 12, continued

Cost Element	Complete-Contract Option (C)	Partial-Contract Option (PC)	All-Military Option (AM)
Revegetation			$7,056
<u>Operations & Maint. (Present Worth)</u>			
Personnel			$188,316
Fuel & Maint.			$12,000
Utilities	in unit fee		Not Applicable
Collection and Analysis of groundwater			$3,080
Testing and Analysis of waste			$3,600
Lump Sum Unit Costs	5¢ per lb	insufficient data	Not Applicable
<u>One-Time Post Closure Care Cost (Present Worth)</u>			
Decontamination & decommissioning			$2,175
<u>Annual 20-Year Total of Expense</u>			
Perpetual Monitoring	in unit fee		$5,400
<u>Miscellaneous</u>			
Profit			$61,982
Transportation			$6,976
TOTAL (≈)	$1,400,000 (for 20 years of complete-contract disposal)	Insufficient Data	$1,300,000 (for a 20-year operating life & 30 years of post closure monitoring)

The classification for the complete-contract option (C) and the all-military option (AM) is derived through the computations shown below:

Option	Conservatively Estimated Personnel Costs	Savings
AM	$180,000	$16,000
C	(14% of $1,400,000 = $196,000)	

(NOTE: 14% represents the percent of personnel cost within the smaller scale operation (the all-military arrangement). As such, it is believed a high estimate for the larger scale. See Figure 8 presented in Chapter III.)

Criterion of significant difference =

10% of $180,000 = $18,000 (20:9)

$18,000 > $16,000; thus the difference is not significant and both options are classified "S".

Insufficient data are available to compare the partial-contract option. The partial-contract arrangement refers to the situation in which the Air Force relies upon a civilian contractor to pick up and transport the waste, and to construct, operate, maintain, and monitor a disposal facility on DOD land. Bid quotes applicable to the partial-contract arrangement would be helpful in completing the economic analysis, but since insufficient information is available to evaluate the economic status of this option, the assimilation table will utilize the similar (S) preference rating only for the complete-contract option and the all-military option. These derived preferences, which are based upon economy, must be considered in conjunction

with the preferences based upon risk.

Risk Analysis

Step #6 involves judging the relative amount of risk associated with each disposal arrangement for IWTP sludges. Tables 13, 14, and 15 indicate the author's weighting scheme.

According to this subjective evaluation, the overall risk is greatest for the all-military option (AM) because lawsuits against the AF or its members are more likely, and damage to Air Force equipment and property are more likely. The complete-contract option (C) is more likely to cause operational delay. However, it is believed that this delay would not produce a catastrophic consequence for the Air Force. The complete-contract option is thus preferred over an AM arrangement. Likewise, the partial-contract (PC) is more likely to cause operational delay when compared to AM. But the partial-contract option also makes more Air Force equipment and property vulnerable to damage when compared to C, so PC is classified between C and AM (see Table 16).

Now that economics and risks have been separately analyzed, the next step is to assimilate the preferences for both risk and economy and to choose the arrangement(s) which best satisfies established policy.

TABLE 13

Subject Risk Analysis of All-Military Option (AM)
Waste Type: IWTP Sludges

Nature of Consequences	Immediate		Future		Sum of Products
	Rank = 4 Catastrophic	Rank = 2 Ordinary	Rank = 3 Catastrophic	Rank = 1 Ordinary	
Fatality Rank = 3	0	0	0	0	0
Morbidity Rank = 3	0	0	0	0	0
Perceived Threat of Liability Rank = 2	5 (2•4•5) +	5 (2•2•5) +	5 (2•3•5) +	5 (2•1•5) =	100
Property Damage Rank = 2	N/A	4 (2•2•4)	N/A +	4 (2•1•4) =	24
Operational Delay Rank = 2	N/A	1 (2•2•1)	N/A +	1 (2•1•1) =	6
Equipment Damage Rank = 2	N/A	4 (2•2•4)	N/A +	4 (2•1•4) =	24
Environmental Damage Rank = 1	N/A	0	0	0	0
				Total Score	154

Weight: X = 0 if all options judged similar
= N/A if combined event and consequence is not envisionable
= some value in range of 1 to 5. "1" represents less risk as compared to "5" representing most risk.

TABLE 14

Subject Risk Analysis of Complete-Contract Option (C)
Waste Type: IWTP Sludges

Nature of Consequences	Immediate				Future			Sum of Products
	Rank = 4 Catastrophic		Rank = 2 Ordinary		Rank = 3 Catastrophic		Rank = 1 Ordinary	
Fatality Rank = 3	0		0		0		0	0
Morbidity Rank = 3	0		0		0		0	0
Perceived Threat of Liability Rank = 2	1 (2•4•1)	+	1 (2•2•1)	+	1 (2•3•1)	+	1 (2•1•1) =	20
Property Damage Rank = 2	N/A		1 (2•2•1)		N/A	+	1 (2•1•1) =	6
Operational Delay Rank = 2	N/A		4 (2•2•4)		N/A	+	4 (2•1•4) =	24
Equipment Damage Rank = 2	N/A		1 (2•2•1)		N/A	+	1 (2•1•1) =	6
Environmental Damage Rank = 1	N/A		0		0		0	0
							Total Score	56

Weight: X = 0 if all options judged similar
= N/A if combined event and consequence is not envisionable
= some value in range of 1 to 5. "1" represents less risk as compared to "5" representing most risk.

TABLE 15

Subject Risk Analysis of Partial-Contract Option (PC)
Waste Type: IWTP Sludges

Nature of Consequences	Immediate				Future				Sum of Products
	Rank = 4 Catastrophic		Rank = 2 Ordinary		Rank = 3 Catastrophic		Rank = 1 Ordinary		
Fatality Rank = 3	0		0		0		0		0
Morbidity Rank = 3	0		0		0		0		0
Perceived Threat of Liability Rank = 2	3 (2•4•3)	+	3 (2•2•3)	+	3 (2•3•3)	+	3 (2•1•3)	=	60
Property Damage Rank = 2	N/A		4 (2•2•4)		N/A	+	4 (2•1•4)	=	24
Operational Delay Rank = 2	N/A		3 (2•2•3)		N/A	+	3 (2•1•3)	=	18
Equipment Damage Rank = 2	N/A		1 (2•2•1)		N/A	+	1 (2•1•1)	=	6
Environmental Damage Rank = 1	N/A		0		0		0		0
							Total Score		108

Weight: X = 0 if all options judged similar
= N/A if combined event and consequence is not envisionable
= some value in range of 1 to 5. "1" represents less risk as compared to "5" representing most risk.

TABLE 16

Risk Analysis Summary

Option	Score	Classification
All-Military (AM)	154	Least Preferred (L)
Partial-Contract (PC)	108	Mid-Preference (M)
Complete-Contract (C)	56	Most Preferred (MP)

Assimilating the Preferences for Risk and Economy

Step #7 identifies the appropriateness of each disposal arrangement in view of the results of the economic and risk analyses. The final action in the procedure is to use Table 17 to link the preference for risk and economy.

The top block in Table 17 applies to the complete-contract option (C), which has the most preferred (MP) risk. The C option had an "S" rating for economy. Table 17 identifies the appropriateness of the C option at the intersection of the MP column for risk with the S row for economy. According to this procedure, the complete-contract option is appropriate for Hill AFB.

The bottom block in Table 17 applies to the all-military option (AM), which has the least preferred (L) risk. The AM option also had an S rating for economy. Table 17 identifies the appropriateness of the AM option at the intersection of the L column for risk with the S row for economy. According

to this procedure, the AM option is not appropriate for Hill AFB.

The middle block in Table 17 applies to the partial-contract option (PC), which has the mid-preference (M) for risk. The economy for PC could not be specifically classified due to insufficient data. Even if such data were available, there is a 2/3 chance that the partial-contract option would fall into the undeterminable range. Since the complete-contract and all-military options already have an S classification for economy, the partial-contract's classification for economy must necessarily be along either the MP, S, or L rows. The intersection of these rows with the M column shows that two of the three possibilities are questionable.

TABLE 17

Assimilating the Preferences for Risk and Economy

ECONOMY	RISK: MP	2H	S	M	2L	L
"Complete-Contract Option (C)"						
MP	C	ok	ok	?	?	No
2H	ok	ok	ok	?	?	No
S	ok	ok	ok	?	No	No
M	?	?	?	?	No	No
2L	?	?	No	No	No	No
L	No	No	No	No	No	No
"Partial-Contract Option (PC)"						
MP	PC	ok	ok	?	?	No
2H	ok	ok	ok	?	?	No
S	ok	ok	ok	?	No	No
M	?	?	?	?	No	No
2L	?	?	No	No	No	No
L	No	No	No	No	No	No
"All-Military Option (AM)"						
MP	AM	ok	ok	?	?	No
2H	ok	ok	ok	?	?	No
S	ok	ok	ok	?	No	No
M	?	?	?	?	No	No
2L	?	?	No	No	No	No
L	No	No	No	No	No	No

ok = appropriate disposal arrangement
? = uncertain
No = not appropriate for a disposal arrangement

CHAPTER V

SUMMARY

As the preceding review of literature pointed out, decisions concerning disposal of hazardous waste must be made after consideration of the costs and risks inherent in each option. Requirements imposed by law, regulation, and policy compel planners to place cost and risk at the center of the decision-making process.

Also as noted previously, the quantitative nature of cost analysis makes this the easier of the two areas to evaluate. In contrast, risk analysis is still largely subjective in nature, with quantification applied only to weigh subjective judgments. Nonetheless, decisions cannot be delayed until the science of risk analysis becomes totally quantitative using objective techniques. The model presented in this report incorporates available techniques in both these areas.

Since conclusions have been stated at appropriate points throughout the discussion, and since the application of the model to the Hill AFB site supports the major conclusion that the model is a useful tool for analyzing disposal options, it is appropriate here to recommend some topics for further research aimed at strengthening the model.

First, research is needed on ways to objectively determine the dollar value of risks. Such additional information

would permit a policy for tradeoffs between risk and economy to be more easily defined.

Second, the model uses information on costs that were determined from secure landfill disposal activities in the civilian sector. The costs need to be refined so that they apply to what military managers actually must face. To serve this purpose, official definitive drawings for a secure landfill are needed so that the costs for the facility can be based upon an officially defined reference rather than the author's defined reference landfill. Therefore, it is recommended that AFESC develop official definitive drawings along with criteria for a secure landfill on military property. The development should be carried out by reference to the following documents:

Landfill and Surface Impoundment Performance Evaluation (EPA Pub SW 869 - cost $9)

Lining of Waste Impoundment and Disposal Facilities (EPA Pub SW 870 - cost $30

Landfill Design - Liner Systems and Final Cover (EPA office library document

Third, official master specifications would also help managers understand what actions are necessary to protect the Air Force's interests. Specifications covering pickup, transportation, site operation, maintenance, and monitoring would help standardize disposal activity. The history of costs for the more standardized activities could eventually form a data base which contributes to the desired refinement of cost for arrangements involving the military. It is recommended that

the Air Force Management Engineering Agency (AFMEA) develop a performance work statement (PWS) for the recurring disposal of hazardous waste. This PWS could serve as a standardized master specification guide for individual bases. This PWS might be composed by incorporating ideas available in the existing performance work statement for refuse disposal with the experience available in the Defense Property Disposal Service's contracting division for environmental protection (DPDS-HC). It is further recommended that HQ USAF define the Air Force's policy regarding the construction of secure landfill disposal facilities on military property, and that Base Civil Engineers ensure that costs for hazardous waste disposal are collected under work order numbers that delineate between different disposal techniques and different categories of waste.

Fourth, persistent efforts are directed at both placing tighter controls on disposal activities and requiring more extensive financial responsibility (12). This fact suggests that disposal costs will continue to rise as a result of RCRA. The prospects of higher costs, an expanding population relying upon existing disposal facilities, regional shortages of disposal facilities, and political opposition for siting are possible future reasons which may justify the Air Force establishing its own secure landfills on DOD property (1). The model must be adjusted whenever substantive changes occur in the areas of policy change concerning waste disposal.

Fifth, research should be undertaken to develop a more

comprehensive decision model which is capable of identifying appropriate disposal techniques. The larger model could perhaps be developed as a follow-on thesis which compares landfills with other techniques, such as incineration, deepwell injection, ocean disposal, and alteration by chemical or biological agents.

The research reported in this study revealed policies affecting use of the model. One example involves the current presidential policy of relying upon the civilian sector for services only if the services are not a governmental function. This policy makes contract options more attractive, because they demonstrate support of executive policy for a service (disposal) that is allegedly not strictly a governmental function.

Another example of policy affecting the model's use involves the Air Force advocating disposal in regional disposal systems. The concept of a regional disposal system is exercised solely in the context of the civilian sector. When a regional disposal system is available, existing Air Force policy is best supported by selecting the complete-contract option in lieu of the other arrangements described in this study.

However, to cover those situations where the preferred option will be other than total contract, it is recommended that HQ USAF support draft legislation proposed by HQ AFLC/DE amending the Resource Conservation and Recovery Act to

eliminate the personal liability now imposed upon the Base Commander.

AD-A123 742 A DECISION MODEL FOR EVALUATING LAND DISPOSAL OF HAZARDOUS WASTES(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYSTEMS AND LOGISTICS K M STONER OCT 82 AFIT-LSSR-65-82 2/2

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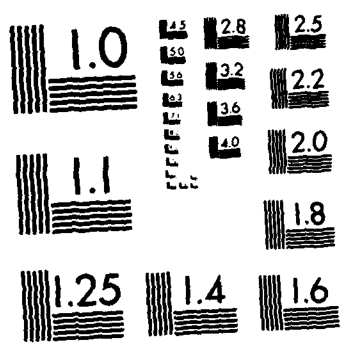


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX A

LEGISLATIVE AND REGULATORY REQUIREMENTS FOR CONTROLLING IWTP SLUDGES

These legislated requirements are listed under applicable Federal Regulation Code (CFR) (1; 53; 54; 55).

Title 40 CFR Part 262 - Standards Applicable to Generators of Hazardous Waste:

- Determine character of waste by laboratory testing if necessary
- Obtain an EPA identification number
- Prepare a manifest for offsite transport
- Maintain records for at least 3 years
- Submit annual reports

Title 40 CFR Part 263 - Standards Applicable to Transporters of Hazardous Waste:

- Obtain an EPA identification number
- Comply with stated manifest procedures
- Maintain records for at least 3 years
- Clean up and report spills

Title 40 CFR Part 264 - Standards Applicable to Owners and Operators of Treatment, Storage, and Disposal Facilities (TSD):

- Obtain an EPA identification number
- Obtain a detailed chemical and physical analysis of waste
- Provide a 24-hour security system
- Follow a self-generated inspection schedule
- Remedy deterioration of equipment or structures which could lead to health hazard
- Maintain records of activity, quantity, locations, reports, inspections, etc. for at least 3 years
- Train personnel, supervise untrained personnel, record introductory and continuing training
- Develop a contingency plan for emergencies
- Protect 100-year floodplains
- Avoid areas within 61 meters of active fault lines
- Equip facility with the following unless Regional Administrator waives requirement:

- a two-way communications system to summon emergency response
- an internal communications or alarm system
- portable fire control equipment and decontamination equipment
- adequate water supply for a hose or spray system

- Designate at least one person as an emergency coordinator
- Comply with specified manifesting procedures
- Provide a synthetic liner unless requirement is waived by EPA or an EPA-approved state program
- Provide features which divert surface water from running onto the landfill

Title 40 CFR Part 265 - Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities:

- Provide a groundwater monitoring system unless waived by EPA or an EPA-approved state program
  - at least one well on hydraulic upgradient
  - at least three wells on hydraulic downgradient
- Perform a groundwater assessment
- Develop a closure plan
  - post closure use of property cannot disturb integrity of containment system
- Provide post closure care for at least 30 years
- File survey plot of landfill with local land authority
- Ensure property deeds are notated to indicate the land has been used to manager hazardous waste
- Maintain a cost plan for facility closure and for post closure monitoring and maintenance
- Waste containing free liquid is controlled by an extra requirement which generally requires that the free liquid must be eliminated by mixing with an absorbant solid or stabilizing by chemical or physical treatment

Title 29 CFR 1910.1000 in accordance with the Occupational Safety and Health Act (OSHA):

- Mark, label, placard, and follow procedures for transporting offsite
- Report accidental spills to the Department of Transportation (DOT)

Title 40 CFR 122, 123, and 124 - Consolidated Permit Regulations (RCRA Hazardous Waste):

- Apply for a permit to operate
- Comply with state's permit requirements in lieu of RCRA permit procedures in those states that have management programs approved by EPA

RCRA Subtitle F requires all federal organizations to comply with the state, interstate, and local requirements applicable to waste disposal in the respective organization's areas. More stringent regulations than those contained in RCRA may exist at the state, interstate, and local levels. EPA regulations represent minimum criteria to satisfy RCRA, so state programs may impose more stringent criteria which the installation must meet. States cannot, however, impose a requirement that interferes with the free movement of hazardous waste across state boundaries to disposal facilities holding a RCRA permit. As of 23 September 1982, the following states had received EPA approval to at least partially control wastes within their borders (1:B-14):

Alabama	Maryland
Arkansas	Massachusetts
Arizona	North Carolina
California	New Hampshire
Connecticut	Nebraska
Delaware	Oklahoma
Florida	Oregon
Georgia	Pennsylvania
Iowa	Rhode Island
Indiana	South Carolina
Illinois	Texas
Kentucky	Tennessee
Kansas	Utah
Louisiana	Vermont
Montana	West Virginia
Maine	Wisconsin
Mississippi	

APPENDIX B

PARTIAL DECONTAMINATION CERTIFICATE

Partial Decontamination Certificate

This real property has been partially decontaminated and does not present a hazard to the general public, if use is restricted to the limitations shown below. The level of decontamination precludes all liability to the Government resulting from indiscriminate disposal or mishandling of the property. The property use is limited to the following and these should be placed in the property's title:

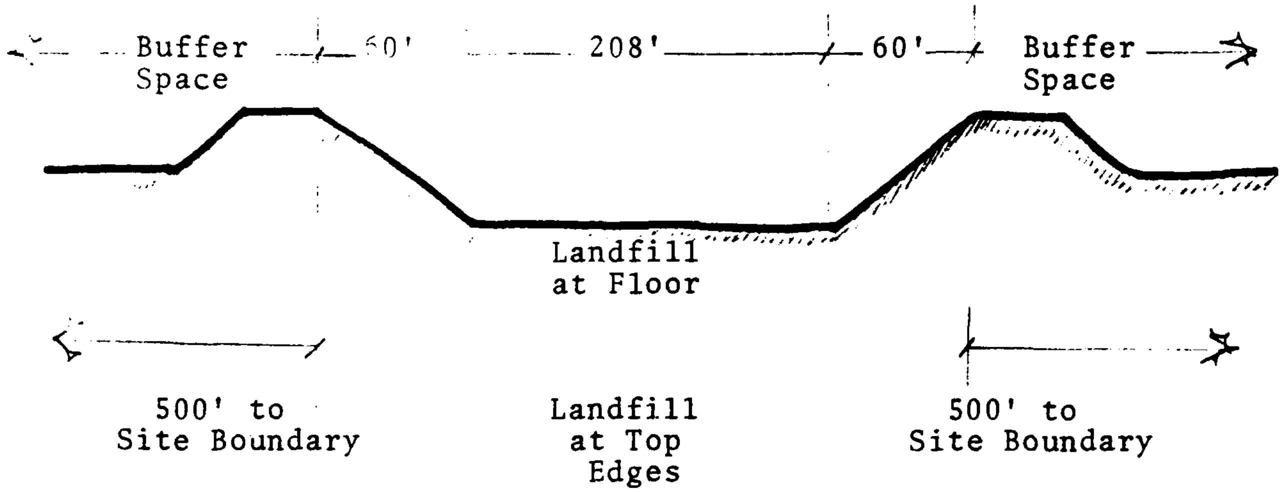
____
Base Commander/MAJCOM Chairperson
Environmental Protection Committee

Description/Name of Area being excessed: ______________________
____
____

Source: (56)

APPENDIX C

AN ESTIMATE OF THE MILITARY LAND REQUIRED FOR DISPOSAL OF AIR FORCE IWTP SLUDGES IN 25 SECURE LANDFILLS



Assume Square Facility:

208' } length of
+ 120' } operational area

+1000' buffer space & support area

1328' = length of one side
x1328'

1763584 sq ft
÷ 43560

40.5 acres ≈ 41 acres per site
x25 sites

1025 Total acres for all sites
÷ 540110 acres for 72 sites (bldg area excluded)

.0018 ≈ .2% > Area Required

APPENDIX D

COMMERCIAL DISPOSERS OF IWTP SLUDGES

Browning-Ferris Industries, Inc.
P.O. Box 3151
Houston, TX 77001
(713)870-8100

BKK Corporation
2550 237th Street
Torrance, CA 90505
(213)539-7150

Chemical Waste Management, Inc.
3003 Butterfield Road
Oak Brook, IL 60521
(312)654-8800

Chem-Security Systems, Inc.
P.O. Box 1866
Bellevue, WA 98009
(206)827-0711

Conversion Systems, Inc.
115 Gibralter Road
Horsham, PA 19004
(215)441-5900

EMPAK, Inc.
2000 West Loop South
Houston, TX 77027
(713)623-0000

Environmental Elements Corporation
P.O. Box 1318
Baltimore, MD 21203
(301)368-7197

Environmental Waste Removal, Inc.
130 Freight Street
Waterbury, CT 06702
(203)755-2283

Force, Inc.
P.O. Box 9484
Houston, TX 77011
(713)928-2737

Genstar Conservation Systems
177 Bovet Rd, #550
San Mateo, CA 94402
(415)570-6211

ILWD, Inc.
7901 W. Morris Street
Indianapolis, IN 46231
(317)243-0811

Industrial Wastes, Inc.
P.O. Box 222
New Brighton, PA 15066
(412)843-8130

IT Corporation
336 West Anaheim Street
Wilmington, CA 90744
(213)830-1781

John Sexton Contractors Company
1815 South Wolf Road
Hillside, IL 60162
(321)449-1250

LIQWACON Corporation
Norristown & Narcissa Roads
Blue Bell, PA 19442
(215)825-2100

Mill Service, Inc.
1815 Washington Road
Pittsburgh, PA 15241
(412)343-4906

Mobley Industries, Inc.
P.O. Box 9987
Austin, TX 78766
(512)454-5122

TRICIL, Inc.
101 Queensway West, #400
Mississauga, Ontario, Canada L5B 2P7

US Ecology, Inc.
1100 17th Street, N.W., #1000
Washington D.C. 20036
(202)785-4705

US Pollution Control, Inc.
2000 Classen Center, Suite 320 South
Oklahoma City, OK 73106
(405)528-8371

Source. (42)

APPENDIX E

TYPES OF COST

Controllable costs are those costs subject to direct control at some level of managerial supervision.

Discretionary costs, often termed "escapable" or "avoidable" costs, are those costs which are not essential to the accomplishment of a managerial objective.

Direct costs are those costs obviously traceable to a unit of output or a segment of business operations.

Differential costs are costs that are not the same for the alternatives being considered.

Fixed costs are those costs which do not change in total as the rate of output of a concern or process varies.

Historical cost is cost measured by actual cash payments or their equivalent at the time of outlay.

Imputed costs are costs that do not involve at any time actual cash outlay and which do not, as a consequence, appear in the financial records; nevertheless, such costs involve a financial loss which is attributed to some person or persons.

Indirect costs are those costs not obviously traceable to a unit of output or to a segment of business operations.

Noncontrollable costs are those costs not subject to control at some level of managerial authority.

Nontraceable costs are not directly identified with the responsibility centers which they are assigned to.

Opportunity cost is the measurable advantage foregone as a result of the rejection of alternative uses of resources, whether of materials, labor, or facilities.

Out-of-pocket costs are those costs which, with respect to a given decision of management, give rise to cash expenditure.

Postponable costs are those costs which may be shifted to the future with little or no effect on the efficiency of current operations.

Period cost is that cost associated with the value of a time period.

Sunk costs are historical costs which are unrecoverable in a given situation.

Traceable costs are directly associated with and assigned to responsibility centers.

Variable costs are those costs which do change in total with changes in the rate output.

Source: (16)

APPENDIX F

COST DATA - CURRENT VALUES AND PRESENT WORTH FOR 20 YEARS OF OPERATING LIFE

Key for Sources used in this Appendix:

a. (23)

b. (16:76; 22:462-463)

c. (37:3-1 to 4-3)

d. (8:99)

e. (27:99, 100, 103, 147)

f. (35)

g. (6:81)

h. (8:E-4, B-1 to B-34)

i. (20)

ADMINISTRATIVE, REPORTING & RECORDKEEPING COSTS

(Present Values)

Manifest handling, signing, preparation for offsite disposal	\$302.50/yr[h]
Disposal report to EPA required for disposal by generator (either offsite or onsite)	\$67.00/yr[h]
Report on non-recepted waste (infrequent for offsite disposal)	\$19.00/yr[h]
Recordkeeping (either offsite or onsite) manifests, reports	\$110.00/yr[h]
Application for onsite disposal, status & maintenance of permit records (onsite)	\$1845.00 one time[h]
Maintenance of training records (onsite)	\$128.00/yr[h]
Maintenance of disposal records, annual reports (onsite), and groundwater monitoring test reports	\$901.00/yr[h] \$1364.00 one time[h]
System Design and Setup	\$695.00 one time[h] + \$3 per shipment[h] + \$600/yr[h] or
Lump Sum for System Design and Setup	6% of \$4000/yr[e]
Waste Analysis Plan (onsite)	\$3014.00 one time[h]
Development of post closure plan and closure plan (onsite)	\$1430.00 one time[h]
Inspections & Review of Regulations (onsite)	\$1137.00/yr[h]
Training Costs (onsite)	\$300 per person/yr[h]
Development of Contingency Plan (onsite)	\$1350.00 one time[h]
Cost of Administering Contract	4% of expected cost[i]

CAPITAL COSTS (Present Value):

Land		\$125 to \$5,000/acre[a]
Building (optional)		\$10,000[a]
Equipment:	Front end loader	\$33,000 each[a]
	Scraper	\$180,000 each[a]
	Bulldozer	\$100,000 each[a]
	Trailer	\$5,000 each[a]
	Pickup Truck	\$12,000 each[a]
	Tractor	\$30,000 each[a]
Excavation		\$2.50/cm[a] or \$2-4.50/cy[c] or \$3.50/cm[e] or
Borrow Excavation	- Rock	\$13-\$23/cy[c]
" "	- Select Gravel	\$10-\$16/cy[c]
" "	- Crushed Stone 3/4"	\$9.50/cy[c]
" "	- Bank Run Gravel	\$5.00/cy[c]
" "	- "Run of the Bank"	\$6.00/cy[c]
" "	- Earth	\$2.50-\$5.00/cy[c]
" "	- Earth-Select	\$7.00/cy[c]
" "	- Native Clay	\$3.25-\$6.00/cy[c]
Monitoring Wells		\$3000 each[a] or \$75 per vert. yd[c] + \$2500 per well[e] or \$6000 each[e] avg 58 ft depth or \$25 per ft[g] or \$2300-\$10,800[h] (avg \$6400 per well)
Collection/Surface Water Diversion		
Collection Ditch		\$19/m[a] or \$2.50-\$7.50/sq yd[c] \$14.66-\$20.20/yd[c] or
3 ft wide, 10 ft deep trench filled with gravel		\$20 per m[e] \$150/yd[c]
2 ft wide, 2 ft deep ditch		\$15-\$20/yd[c]

Leachate Drainage & Collection System	
Double lined -	$398,000[a]
Single lined -	$200,000[a]
	or
	$23-$68/yd
	$300 each pump[c]
Vitrified Clay Pipe - Perforated	$3.70/ft[c]
Portable 3 h.p. Well Pump	$2850 each[c]
	and
Leachate Treatment System	
Double lined -	$100,000[a]
Single lined -	$50,000[a]
2-inch Wellpoint	$22.50/ft[c]
4-inch Wellpoint	$30.00/ft[c]
Liners:	
Clay	$5/sq m[a]
Synthetic	$8/sq m[a] (36 mil) or 27K to 70K per acre[c] or 30 mil Hypalon with 2 ft of clay - $22.50/sq m[e]
Butonite, 2" layer spread and compacted	$1.40/sq yd[e]
PVC, 20 mil., installed	$1.30-$2.00/sq yd[e]
Chlorinated PE, 30 mil., installed	$2.40-$3.20/sq yd[e]
Elasticized polyolefin membrane, inst.	$2.70-$3.60/sq yd[e]
Hypalon membrane, installed (30 mil.)	$6.50/sq yd[e]
Neoprene membrane, installed	$5.00/sq yd[e]
Ethylene propylene rubber, installed	$2.70-$3.80/sq yd[e]
Butyl rubber membrane, installed	$2.70-$3.80/sq yd[e]
Standby equipment or replacement equipment	$5,000 @ 7 yrs[c] or $382,000 @ 10 yrs[a] $328,000 @ 10 yrs[a]
Standby (optional)	$10,000 one time[h]
Clearing and Grubbing	$2,000 per 2.5 acre[e]
Access Road	$65.5 m - permanent[e] $19.6 m - temporary[e] (5.4 m wide)
10,000 gal Water Tank Rinse System	$10,000[e]
Communication Equipment	$500[e]
Electric Generator	$4000 each[g]
Office and Storage Building	$733/sq m[e]

Fencing:	\$20-\$40/m [a]
	or
	\$50/m [e]
	or
	\$10,000 mt/yr=\$11200 [h]
	\$20,000 mt/yr=\$13900 [h]
	\$50,000 mt/yr=\$18600 [h]
Soil Testing, Complete Series	\$216.00 [c]
Hydrometer Analysis and Specific Series	\$60.00 [c]
Sieve Analysis, washed	\$8.00 [c]
unwashed	\$50.00 [c]
Moisture Content	\$8.00 [c]
Permeability	\$50.00 [c]
Proctor Compaction	\$40.00 [c]
Geotechnical and Hydrological Testing	\$10,000.00 [c]

An Example Summary of Capital Costs for a
9-1/2 Acre Landfill
(43:216)

Capital Cost Category Module	Costs†							
	Site Preparation	Structures	Mechanical Equipment	Electrical Equipment	Land	Other	Total	Land (ft^2)
Land disposal site	$ 121,000	$ 1,680,000	$ 230,000	$ 4,000	$ 31,100	$ 122,000	---	418,000
Total	121,000	1,680,000	230,000	4,000	31,100	122,000	---	418,000
Supplemental capital costs	---	---	---	---	---	---	---	---
Subtotal of capital costs	---	---	---	---	---	---	$ 2,188,100	---
Working capital**	---	---	---	---	---	---	13,630	---
AFDC ‡	---	---	---	---	---	---	109,405	---
Grand total of capital costs	---	---	---	---	---	---	2,311,135	---

* Scale = 1,000 lb/hr.

† Mid-1978 dollars.

** At one month of direct operating costs.

‡ Allowance for funds during construction at 5% of capital costs.

OPERATING AND MAINTENANCE COSTS (Present Values):

Monitoring/Testing	
Testing & Analysis of Waste (onsite) (see Table 1)	\$600-\$3400/yr[h]
Testing and Analysis of Waste (offsite) (discretionary)	\$150-\$250/yr[h]
Analysis of Groundwater Samples (discretionary)	\$3080 per site[h]
Collection & Analysis: double-lined	\$12,800/yr[a]
single-lined	\$6,400/yr[a]
Labor/Services	
Security Service (50-acre site)	\$12,000/yr[a]
Foreman/Supervisor	\$40,000/yr[a]
Laborers	\$20,000/yr[a] or 6% of \$29,000/yr[e]
Equipment, Fuel & Maintenance	\$50-\$100,000/yr[a]
Utilities	\$2,000-\$2,500/yr[a]
Backdozer - dozer 300 h.p.	\$.75/cy[c]
Backfill - rubber wheel loader	\$.90/cy[c]
Grading - dozer 75 h.p.	\$2.50/cy[c]
Grading - scraper towed 3 yd^3 capacity	\$1.75/cy[c]
Grading - dozer 300 h.p.	\$1.50/cy[c]
Grading - fly ash or sludge	\$1.00-\$1.75/cy[c]
Compaction - vibrating plate	\$2.00/cy[c]
Compaction - wobble wheel roller	\$1.50/cy[c]
Compaction - dozer with roller	\$1.25/cy[c] or
Drainage Systems	7% of initial capital cost[c]
Drainage Systems - trenches	4% of initial capital cost[c]
Drainage Systems - recharge	2% of initial capital cost[c]
Grading and Revegetation	3% of initial capital cost[c]
Surface Capping	5% of initial capital cost[c]
Liners	5% of initial capital cost[c]
Subsurface Drains & Dewatering	5% of initial capital cost[c]
Extraction Wells	6% of initial capital cost[c]
Leachate Collection System	4% of initial capital cost[c]
Groundwater Monitoring	\$400/sample + 1%/well of initial capital cost[c]
Collection Removal and Venting	9% of initial capital cost[c]
Access--Fence	4% of initial capital cost[c]

CAPITAL COSTS AT CLOSURE (Present Values):

Cover Cap:	Synthetic	\$4.5/sq m[a]
	Clay	\$5/sq m[a]
		or
Cover Cap	Relative Cost	6" clay/unit[g]
		18" clay 1.28 unit[g]
		30 mil PVC 2.43 unit[g]
		or
Cover Cap (\$=283x.597, where x=mt/yr)		\$10,000 mt/yr = \$51,900[h]
		\$20,000 mt/yr = \$78,200[h]
		\$50,000 mt/yr = \$134,000[h]
Revegetation		\$1.25/sq m[a]
		\$.635/sq m[a]
		or
Revegetating & Regrading for 4 hectares		\$151,000-\$278,000[g]

POST CLOSURE CARE COSTS (Present Values):

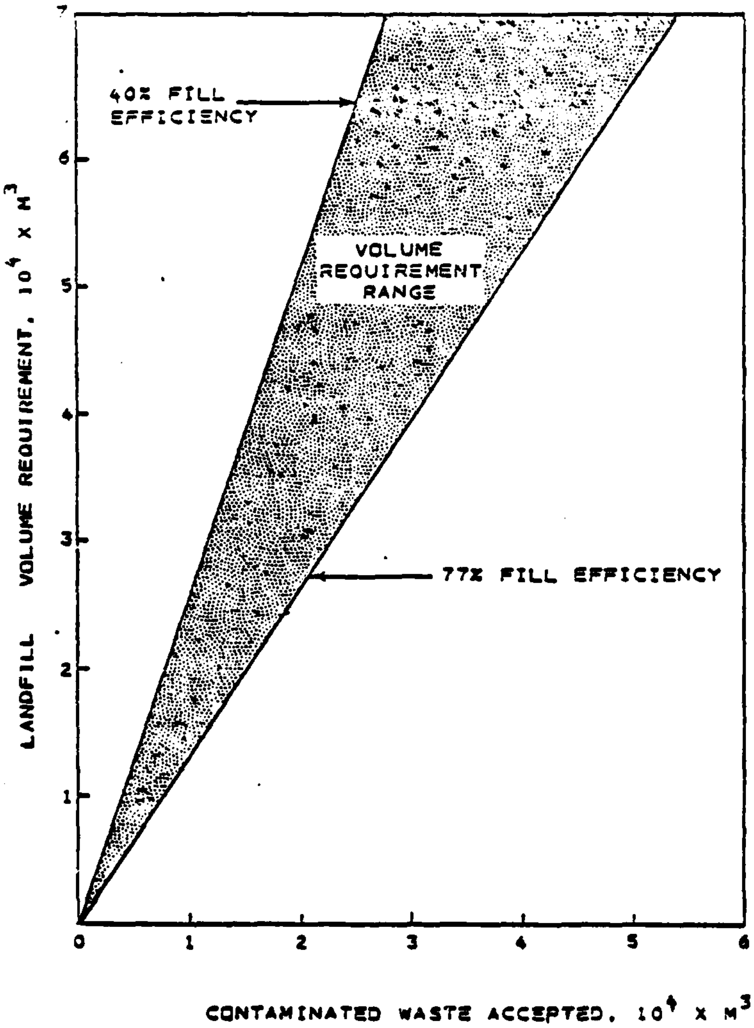
Double-lined landfill (annually)	\$2,000 per 25 acres[a]
Single-lined landfill (annually)	\$1,000 per 25 acres[a]
	or
	\$10,000/yr[c]
One-time Decontamination & Decommissioning	\$1000 mt/yr = \$2175[h]
	\$5000 mt/yr = \$2705[h]
	\$20000 mt/yr = \$4250[h]
	\$50000 mt/yr = \$7350[h]
Annual Expense	\$1000 mt/yr = \$3950[h]
	\$5500 mt/yr = \$5810[h]
	\$20000 mt/yr = \$12030[h]
	\$50000 mt/yr = \$24650[h]
Perpetual Monitoring	\$4,270[a]
	or
	\$1,070[a]
	or
	\$5,400[e]
	or
	\$1,000/yr[g]
	or
	\$140,000-\$575,000 for 4 hectares[g]
	or
	\$400 per well 4 times/yr[c]

MISCELLANEOUS COSTS (Present Values):

Discount Rates	3%[a] or 0-20%[b] or 0.5%-18%[h]
Engineering	9% of construction cost[c]
Contingency	15% of construction and engineering cost[c]
Offsite/Onsite Decision Breakpoint 10,000 metric tons < send offsite[d]	
Combined fund to provide financial assurance for post closure and closure responsibilities (differential)	$1000 mt/yr = $7095/yr[h] $2000 mt/yr = $8060/yr[h] $5500 mt/yr = $11040/yr[h] $10000 mt/yr = $19955/yr[h] $20000 mt/yr = $22455/yr[h] $50000 mt/yr = $44175/yr[h]
Cited costs on a per unit-of-waste basis: double-lined	$15.70/cm[a]
single-lined	$11.40/cm[a]
unlined	$8.25/cm[a] or $12/ton - nonwetland[c] $30/ton - wetland[c] or $.02 - $.06/lb[e] or $.01 - $.04/lb[f]
Transporter reports and application for ID (differential)	$65 one time[h]
Transporter recordkeeping (differential)	$128/yr[h]
Flat Rate Transportation	50-mile round trip = $3.30/cm[a] or $18.40/cm[a] - 500-mile round trip or
by military -	$.32/mile[e]
by contractor - (vacuum tanker)	$40/hr[e]

APPENDIX G

REQUIREMENTS FOR LANDFILLS



Void Capacity Requirements for Landfills
(43:215)

Estimated Capacity for Various Landfill Sizes

Area of Top (acres)	Top Side Length (m)	Depth (m)	Annual (cm)	Capacity (mt)
.27	33	2	833	1,000
1.11	67	4	8,330	10,000
2.05	91	5	20,800	25,000
3.27	115	6	41,700	50,000
4.98	142	8	83,300	100,000

Source: (8:B-23)

APPENDIX H

COMPUTATIONS FOR APPLIED INFORMAL ECONOMIC ANALYSIS

Calculations for Complete-Contract Option

20 yrs x 657 tons per year x 2000 lbs/ton x \$.05/lb = \$1,314,000 (includes transportation)

See Appendix B, Miscellaneous Costs.

Cost of Administering Contract = 4% x expected cost

(Ref. Admin, Reporting & Recordkeeping Costs

4% x \$1,314,000 = \$52,560

Total Estimate:

\$1,314,000 - complete disposal
\+ \$ 52,560 - contract administration

\$1,366,560 - TOTAL

\$1,366,560 ≈ \$1,400,000

Calculations for All-Military Option

ADMINISTRATIVE, REPORTING, & RECORDKEEPING COSTS:

1. Post closure plan, approx. 1/2 developed:

   1/2 of 1430/1 = 715 $715 = sunk cost

2. Contingency plan, approx. 1/2 developed:

   1/2 of 1350/1 = 675 $675 = sunk cost

3. Training costs:

   $300/person x 1.5 people = $450/yr x 20 yrs = $9000

4. Manifest Handling, Signing & Preparation:

   $302.5/yr x 20 yrs = ¢6,050

5. Recordkeeping: $110/yr x 20 yrs = $2,200

6. Inspection & Review of Regs. (every other year for 20 yrs)

   $1137 x 10 = $11,370

7. Contract Administration to construct facility:

   $626,091 x 1.3 (profit & OH) = $813,918 total
   ($187,827 = profit & OH)
   4% of $813,918 = $32,557

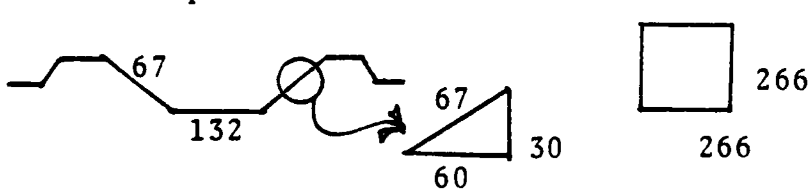
8. Disposal report to EPA: $67/yr x 20 yrs = $1,340

9. Training records: $128/yr x 20 yr = $2,560

CAPITAL COSTS

1. Synthetic Liner & Clay Liner for square landfill:

   $MA_{op} = \sqrt{.4 \cdot 43,560} = 132$ ft $132 + 67 + 67 = 266$



70,756 sq ft for sides and bottom

$(132)^2 = 17{,}424$ sq ft for bottom   Cap $= (132+60+60)^2 = (252)^2 = 63{,}504$ sq ft

$70{,}756\ ft^2 \div 9 = 7{,}862$ sq yd for sides and bottom

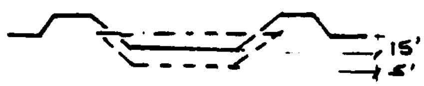
$63{,}504\ ft^2 \div 9 = 7{,}056$ sq yd for cap

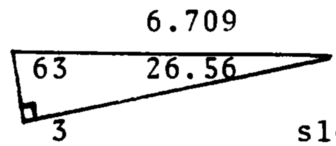
7,862 converted to square meters = 6,290

7,056 converted to square meters = 5,645

6,290 + 5,645 = 11,935 sq m @ $22.50 per sq m = $268,538

2. Excavation: Excavation must go extra 5 ft deeper for lining and 7 ft wider for lining



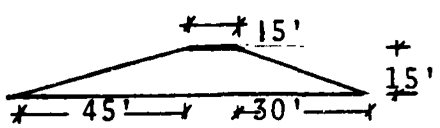


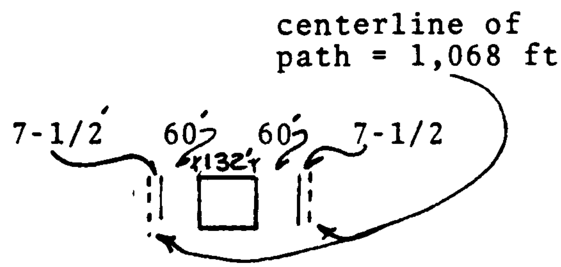
slope = .5

$$
\begin{array}{r}
132' \\
\times\ 20' \\
\hline
2{,}640\ ft^2 \\
\times\ 132' \\
\hline
348{,}480\ ft^3 \text{ "box area"} \\
+390{,}720\ ft^3 \text{ "triangular area"} \\
\hline
739{,}200 \\
+\ 27{,}380 \\
\hline
766{,}580\ ft^3
\end{array}
\qquad
\begin{array}{r}
+37' \\
\times 20' \\
\hline
740\ ft^2
\end{array} \times 132' \times 4 \text{ sides} = 390{,}720\ ft^3
$$

$766{,}580\ ft^3 \div 27 = 28{,}392$ cubic yds x $3.5 per/cy = $99,372

3. Berms:





$$
\begin{array}{rl}
(15)^2 & = 225 \\
1/2(15)(30) & = 225 \\
1/2(45)(15) & = 338 \\
\hline
 & 787.5
\end{array}
$$

787.5 sq ft x 1,068 linear ft = 841,050 cu ft ÷ 27 = 31,150 cu yds

31,150 cy x $6/per cu yd = $186,900 for berms

4. Monitoring Wells:

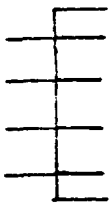
$3000/each x 4 = $12,000

5. Leachate Collection: 2 one-foot layers of select gravel or crushed rock

$(132)^2$ = 17,424 ft^2 x 2 ft = 34,848 ft^3 ÷ 27
= 1,291 cu yd x \$10 per cu yd = \$12,907 for rock layers

6. Portable Pump = sunk cost

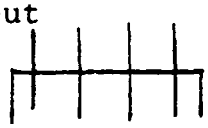
7. Collection Lines:



Primary Layout

132'
x 5
660 ft
+80
740'

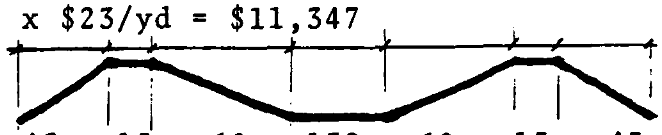
2nd Layout



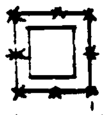
132'
x 5
660 ft
+80 2 runs to surface
740'

1480 ft ÷ 3 = 494 yds x \$23/yd = \$11,347

8. Fencing: 6 ft ht



45 + 15 + 60 + 132 + 60 + 15 + 45



372'

372'
x 4
1,488 linear ft ÷ 3 = 496 yds x .9 = 447 meters

447 m
\- 7 m for gate
440
x \$40 per meter
\$17,600 for fence
+1,500 for gate
\$19,100

9. Access Road:

Road Path around cell = 1068 ft length
Distance to site boundary = 250 ft (estimate)
1068 + 250 = 1318 ÷ 3 = 439.3 x .9 = 396 meters
396 meters x \$20/m = \$7,920 for access road
Temporary road 5.4 m wide

10. Surface water diversion along two high sides:

372 x 2 = 744 ft ÷ 3 = 248 yds x .9 = 224 m x \$20/m = \$4480

11. Revegetation along outer slope:

$$50 \text{ ft} \times 1068 = 53{,}400 \text{ ft}^2 \div 9 = 5{,}933 \text{ sq yds}$$

$$5{,}933 \times .8 = 4{,}747 \text{ sq m} \times \$1.25/\text{sq m} = \$5{,}934$$

12. Equipment Replacement: $5,000 at 7th and 14th yr = $10,000

13. Revegetation of Cap: 7,056 sq yds x .8 = 5,645 sq m x $1.25/sq m = $17,056

OPERATING AND MAINTENANCE COSTS

1. 1 person to haul 2 hr one-way = 4 hr round trip

$$\frac{20 \text{ yrs} \times 657 \text{ tons} \times 2000 \text{ lbs/ton}}{28{,}000 \text{ tons per truck}} = 938.5 \text{ trips (truck loads)}$$

$$4 \times 938.5 = 3{,}754 \text{ hrs per 20 yrs}$$

Load: 939 loads per 20 yrs x 1.5 hrs to load = 1409 hrs/20 yrs

Shop Rate = $16.4 per hr

2. Unload: 939 loads per 20 yrs x .5 hrs = 470 hrs per 20 yrs

Shop rate $16.4 per hr

3. Site Preparation (includes spreading, compacting, building barriers between old and new cells):

1 cell = 15 x 30 x 30

Total Landfill = 30 x 132 x 132

Total Landfill Volume = 38.72 cells ≈ 40 cells

40	cells	40	cells
x 5	layers per cell	x12	hrs per cell to close
200	layers	480	hrs per 20 yrs for closing
x 8	hrs per layer		
1600	hrs per 20 yrs for layering		
+480	hrs for closing		
2080	hrs total for 20 yrs of layering + interim closing of compartmentalized cells within the landfill		

```
 2080 hrs for layering
+3754 hrs for hauling
+1409 hrs for loading
+ 470 hrs for closing
 7713 hrs for personnel for 20 yrs
```

7-1/2 manhours per week per year

```
   386 hrs per year
x$16.4 shop rate
$6,324 per year
```

F/A @ 4%/20 yrs: (6,324)(29.778) = $188,316 total part-time personnel cost

4. Testing & Analysis of waste: $600 per yr x 6 (about every 3 yrs) = $3600 for 20 yrs

5. Collection & Analysis of groundwater: $3,080

6. Utilities: sunk cost

7. Fuels & Maint. needed to run pump, distribute and compact waste.

   est. $50 per month = $600 per yr x 20 yrs = $12,000

MISCELLANEOUS COSTS

1. Transporter report and application for ID = $65

2. Transporter recordkeeping: $128/yr x 20 yrs = $2,560

3. Transportation: 109 miles one-way x 2 = 218 x 5 times a year = 1090 miles/yr x 20 yrs = 21,800 miles x .32 = $6,976

TOTAL COST FOR AM OPTION:

Capital	$643,147 capital items 187,827 profit & OH	
		≈ $830,974
Personnel		≈ 188,316
Administrative Care & Monitoring Transportation		≈ 103,018
		≈ $1,122,308
		≈ $1,120,000
15% for engineering design and contingency		168,000
		≈ $1,300,000

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